INTESA SANPAOLO
INNOVATION CENTER

INDUSTRY TRENDS REPORT

HEALTHCARE, BIOTECH AND PHARMA

DIAGNOSTIC TECHNOLOGIES AND SURGICAL ROBOTS

FROST & SULLIVAN

CONTENTS

EXECUTIVE SUMMARY

With the arrival of Point-of-Care Testing (POCT) for COVID-19, decentralized workflows have driven the global **in vitro diagnostics** markets. Frost & Sullivan believes that the segment represents a continued motor for growth with forecasted revenues of $18.7b in 2022 built on rapid innovation while, more generally, the positive outlook for the IVD space is underpinned by the presence of a rapidly ageing population in developed economies.

This is notably to the advantage of both molecular and tissue diagnostics.

The ***molecular diagnostics*** segment is fragmented with new entrants focusing on niche areas and established participants pursuing chronic diseases. In the latter, liquid biopsies are notably increasingly being used as a biomarker-driven tool for oncology and accelerating the growth of next-generation sequencing.

Here and elsewhere, Artificial Intelligence (AI) is changing the game by, for example, deciphering unseen patterns in very complex molecular data with Machine Learning (ML) enabling cancer discovery. In the longer term, AI-powered molecular diagnostics is expected to pave the way to the development and provision of precision medicine by leveraging algorithms for the pre-symptomatic detection of infections.

Overall, in six years, funding for AI-based molecular diagnostics has exceeded $3b while, in the future, assay-agnostic flexible AI analytics platforms are set to unleash further potential by democratizing and decentralizing molecular testing.

The ***tissue diagnostics*** (TDx) segment is similarly being shaped by innovation with analysis of samples in laboratories now more precise and automated.

Preanalytical staining techniques remain a cornerstone of the market with global sales of $2.6b in 2020 but lack reliability and upgradability. However, advanced staining techniques which offer personalized diagnoses are continuing to gain ground and now represent 58% of revenues. Anatomical Pathology Lab Information Management Systems manage both of these processes and are growing rapidly at 10.6%.

From a supplier perspective, Roche (Switzerland) leads the way and is well positioned with solutions which address the market hotspots. The company is working with GSK (UK) to develop new Companion Diagnostic tests while partnerships with biopharma are now considered to be best practice. Moving forwards, opportunities include extending beyond oncology to enable TDx adoption and embracing Whole Slide Imaging technology to support with caseload management.

As with in vitro solutions, conventional **wound diagnostics** and monitoring methods have their limitations and market participants are seeking alternatives. This is particularly true in the context of the growing burden of chronic wounds.

The application of new advanced technologies brings the promise of greater accuracy, standardization and affordability and reduced patient discomfort. In particular, innovative computing, imaging and sensing is being applied notably in the domains of digital wound assessment and hand-held scanners. In the former, AI, ML and computer vision are minimizing clinic visits and accelerating wound documentation while, in the latter, hyperspectral, fluorescence and biocapacitance technology are enabling early pathogen detection and helping healing.

In the long-term, theranostic products represent the next frontier in wound care.

In addition to AI, **Digital Twins** (DTs) represent a key emerging technology that will shape the diagnostics and broader healthcare space. DTs initially found their use in the production and engineering sectors but can now be applied to humans, devices and hospitals. A human digital twin supports with the delivery of personalized healthcare while, for medical devices, DTs enable improved design and performance and, for hospitals, they provide for ever more dynamic operations and processes.

Overall, the market for DTs in healthcare remains nascent and sizing it can be challenging but Frost & Sullivan expects global revenues to reach $2.4b by 2025. Growth will be aided by the fact that – unlike many other digital solutions – the impact of DTs can quite easily be quantified and assessed while healthcare executives and clinicians are increasingly recognizing the benefits of simulating physical assets which is translating into fresh investment.

This is to the benefit of an emerging vendor ecosystem which includes large equipment manufacturers and smaller firms focused on niche applications and where ultimately success will rest on suppliers' ability to increase quality and cut costs through interoperability and data integration. Clinical trials represent a growth opportunity with DTs being deployed to accelerate drug discovery and development via digital modelling while, in the future, a focus on femtech will facilitate the use of digital twins in addressing women's health.

The ageing population is causing challenges and creating opportunities not only on the demand side but also in terms of supply with retirements expected to provoke a shortfall of between 55,000 and 150,000 physicians globally by 2030.

Surgical robots are one of several emerging solutions which, in addition to Digital Twins, can help to bridge this gap. Robot-assisted Surgical Devices' (RASD) uptake is being driven by their ability to support with Minimally Invasive Surgeries (MIS) with Frost & Sullivan expecting the RASD market to be valued at $14.3b globally by 2026.

Growth will stem largely from instruments and accessories to the advantage of dominant leader Intuitive Surgical (US) which boasts an 81% share globally. The rising demand for portability will however broaden the ecosystem and encourage new entrants.

The advent of AI is improving performance in the RASD space, notably in the areas of human to robot interaction and system modelling and control. This, combined with the transition from multi-port to single site surgery and a shift to address multiple specialties will mean that robotics will gradually become the gold standard of care.

Slowly, market participants are in parallel moving towards a leasing model, which offers mutual benefits to both "sellers" and "buyers", and are also sharpening their focus on enabling microsurgery procedures. In the long run, this and other areas will enable them to untap the ~90% of the market in volume terms which lies beyond MIS.

This paper examines each of these areas in turn with a focus on the way in which innovation is shaping the diagnosis, monitoring and treatment of conditions and diseases. More broadly, it examines how technological advances and new business models are benefiting the patient and provider by providing better healthcare more efficiently.

Source: Frost & Sullivan

IN VITRO DIAGNOSTICS

With the arrival of Point-of-Care Testing (POCT) for COVID-19, decentralized workflows have driven the global *in vitro diagnostics* markets

In vitro diagnostics (IVD) pertain to the reagents, instruments and systems that are intended for the collection, preparation and examination of samples, such as blood, urine and tissue, that have been taken from the human body.

The purpose of such testing is to detect diseases or other conditions and monitor the overall health of a patient to help cure, treat and prevent illness.

The market can be segmented by technology (e.g., POCT) application (e.g., molecular diagnostics) and by workflow. While there is some correlation between each area, there is also overlap which depends on the testing requirements and context.

Centralized, referral and peripheral and decentralized testing constitute the three major workflows or avenues across the clinical and laboratory facilities that employ IVD reagents, instruments and systems for analytical testing.

Centralized testing is *high throughput* and suitable for *expert users*.

For this type of testing, samples are procured at collection sites and then delivered to an equipped laboratory where multiple samples are processed and a variety of tests are run by trained laboratory staff. Centralized testing is typically conducted within a hospital or offsite reference lab. Complex platforms that offer high throughput processing along with automated workflows are used to process hundreds and thousands of samples.

Referral and peripheral testing is *medium throughput* and suitable for *semi-expert users*.

Here, samples are obtained at a collection site and then delivered to a clinical pathology laboratory. The volume of patient samples is relatively low when compared with centralized testing. This type of testing is typically conducted in a hospital or offsite reference lab. Platforms might be complex, catering for medium throughput, as multiple steps are required during analysis and are usually performed by trained pathology staff.

Decentralized testing is *low throughput* and suitable for *non-expert users*.

This segment involves single sample or low volume testing that occurs near the patient at the point of care (POC). Tests are often conducted by a wide variety of clinicians and lab professionals or by the patients themselves. Typically, the instruments used offer portability and rapid turnaround times. Decentralized tests can be performed at a patient's bedside or even at a clinician's office. Other places of deployment include but are not limited to urgent care settings, emergency departments and community pharmacies.

Decentralized POCT and the kit-based segment will witness steady growth and account for 28% of global IVD revenue in 2025. The need for widely available, rapid turnaround testing became more evident during the pandemic. Abbott entered the decentralized lab market with its ID NOW test. Several other participants, such as Thermo Fisher and Hologic, have adopted an acquisitive approach while players such as Bosch, Sense Bio and Nuclein, have also shown an interest in the space. The direct-to-patient approach has intensified since the Covid-19 outbreak with the launch of new at-home collection kits by a wide range of companies including Everlywell, Ambry Genetics, Color Health, Quest and LabCorp.

Source: Frost & Sullivan

Frost & Sullivan believes that the segment represents a continued motor for growth with forecasted revenues of $18.7b in 2022 built on rapid innovation

POCT DIAGNOSTICS MARKET, REVENUES, GLOBAL, 2021-2022

Integrated lab-on-a-chip devices – which combine one or several laboratory functions on a single miniature circuit – supported by microfluidics and biosensors are emerging as ideal platforms in the development of POC tests for the diagnosis of infectious diseases through inexpensive, robust and portable solutions.

These innovations are giving rise to a new vendor ecosystem which features hundreds of tests. Alveo Technologies (US), for example, has launched a rapid solution which blends nucleic acid detection in a highly efficient design package. The device is connected to the cloud to provide inputs on many diseases.

Portable molecular diagnostic (MDx) devices are excellent for detecting infectious diseases because they efficiently reduce long incubation time frames compared with conventional microbiology lab testing. Genomtec, a Polish molecular diagnostic company, plays in this area and received the CE-IVD Mark for its new SARS-CoV-2 EvaGreen Direct-RT-LAMP 2021 which gives sample-to-result in 20 minutes.

Overall, the outlook for POCT remains positive due to the launch of novel rapid techniques as well as the burgeoning demand for alternate testing sites which provide affordable and accessible services and will drive testing volumes. More rapid growth is only restrained by the comparatively high cost of next-generation sequencing, which creates a barrier to large scale implementation, and a lack of interoperability between POCT devices and electronic health data systems, which pose a challenge to using information more efficiently.

Source: Frost & Sullivan

More generally, the positive outlook for the IVD space is underpinned by the presence of a rapidly ageing population in developed economies

This is especially in Europe and countries such as Japan where demographic changes is also coupled with rising awareness amongst end-users of the potential of personalized medicine and an industry shift towards direct-to-consumer diagnostic business models which continues to advance thanks to further telehealth and digital channels.

Developing multiplex assays that integrate separate IVDs and enable lower testing costs and support data generation (as, for example, in POCT) is providing growth opportunities for both existing participants and new entrants.

These players stand to benefit from government expenditure on continued COVID-19 testing and cost-effective automated Immunohistochemistry (IHC) and In Situ hybridization (ISH) instruments for tissue diagnostics which will act as a key growth driver on account of declining number of pathologists.

Overall, advanced automation, together with the Internet of Things (IoT) for connected instruments and Artificial Intelligence (AI) and analytics for improved process flow and efficiency, will become a differentiator for participating players.

This is notably to the advantage of both molecular and tissue diagnostics

Molecular diagnostics refers to tests that look at genetic material, including Deoxyribonucleic acid (DNA) and Ribonucleic Acid (RNA), that may or may not be associated with a disease. MDx covers a multitude of tools, such as microarray, Polymerase Chain Reaction (PCR), sequencing, prenatal testing and liquid biopsies.

Tissue diagnostics (TDx) refers to the examination of a tissue specimen removed during a biopsy or surgical procedure. TDx comprises pre-analytics tools such as histology equipment, Hematoxylin and Eosin (H&E) instruments, tissue processors, slide stainers, cassettes, and tissue-embedding machines, along with advanced stains used in IHC and ISH.

The *molecular diagnostics* segment is fragmented with new entrants focusing on niche areas and established participants pursuing chronic diseases

This fragmentation extends to both technologies and portfolios with areas such as pneumonia offering emerging opportunities while conditions such as cancer remain a core area of focus. Over the last couple of years, major players have witnessed annual revenue growth rates of between 7% and 10% while some newcomers have seen 15% to 30%.

Leading MDx market participants include Illumina, Thermo Fisher, Qiagen, Oxford Nanopore Technologies, Agilent Technologies, Pacific Biosciences of California (PacBio), PerkinElmer, Macrogen, BGI, GENEWIZ (Brooks Automation), Eurofins, Myriad, New York Genome Center, Dante Labs, IDT (Danaher) and Sysmex (NanoString Technologies).

Overall, demand for genetic testing with a focus on precision medicine will drive next-generation sequencing applications while infectious disease testing and monitoring will result in high sales of assays and automated instruments. This positive outlook is tempered by high development costs and long launch timelines for novel applications which leverage next-generation sequencing combined with associated challenges around reimbursement. The advent of the European Union Invitro Diagnostic Regulation (EU IVDR), which entered into application in May 2022, has created further uncertainty and is expected to impact the provision of lab-developed tests (LDTs), including for oncology, as these will be subject to a range of compliance requirements from which they we previously exempt.

Source: Frost & Sullivan

In the latter, liquid biopsies are increasingly being used as a biomarker-driven tool for oncology and accelerating the growth of next gen sequencing

Healthcare is becoming increasingly patient-oriented with an emphasis on providing value-based care. This context presents opportunities for IVD market participants to augment their instrument, assay and informatics capabilities to introduce greater precision to diagnostics and to address unmet clinical needs.

In an era of precision diagnostics, liquid biopsies – which allow analysis of tumors using only a fluid sample rather than a conventional solid tissue biopsy – mean that a patient's response to therapy and disease progression is equally important as the early detection of circulating tumor cells and fragments of nucleic acid in blood.

As a result, the USA FDA approved more than 10 breakthrough devices in 2021.

These designations are expected to boost the development of companion and multi-cancer diagnostics through clinical trials.

The ability to comprehensively profile circulating tumor DNA (ctDNA), circulating tumor cells (CTCs) and immune cells from a single blood draw are a major leap forward in facilitating accurate, powerful clinical decisions. A biomarker-driven strategy demonstrates an inclusive view of tumor genetics and reduces the current siloed landscape of liquid biopsy.

Moving forwards, minimal or molecular residual disease (MRD) monitoring will set a new bar for liquid biopsies. Over the years, low concentrations of CTCs and ctDNA in blood has marked MRD as one of the most challenging clinical phenomena in precision oncology but sensitive liquid biopsy assays can now detect minimal residual disease while enumerating CTCs and ctDNA has the potential to provide valuable molecular insights, aiding timely therapy selection and preventing metastatic relapses.

Liquid biopsy developers are being encouraged to show clinical validity in prospective cohort studies. Demonstrable biomarker performance will ensure private payor market access so understanding payer policies and leveraging real-world evidence (in combination with clinical trial results) is imperative to design and implement an ideal test for reimbursement.

In the longer term, a multi-omics approach, in contrast to single-gene testing, is expected to gain momentum. This will be important to justify the price and show the advantages of using such multi-cancer panel tests in labs.

In the short term, the United States will continue to lead the global market because of its generous reimbursements and early approvals for clinical diagnostics tests and liquid biopsy panels. The Asia-Pacific region also presents opportunities for vendors due to its greater disease burden, the presence of distinct genotypes and the growing trend towards public-private partnerships. Here, the continued success of SCRUM-Japan GI-SCREEN, the nationwide cancer genome screening project, and the recent MONSTAR-SCREEN project for monitoring ctDNA in cancer patients will drive the growth of the clinical next-generation sequencing market. Large-scale projects in China, such as the Neonatal Genome Project and Million Human Genome Project, will propel solutions beyond standard MDx testing.

Source: Frost & Sullivan

Here (and elsewhere), Artificial Intelligence (AI) is changing the game by, for example, deciphering unseen patterns in very complex molecular data

Liquid biopsies have revolutionized molecular diagnostics, especially for cancer diagnosis and prenatal testing where their non-invasiveness and quicker turnaround times are critical. However, the lack of a standardized, unbiased analytical solution that can accurately analyze low ctDNA levels is a key barrier to widespread adoption.

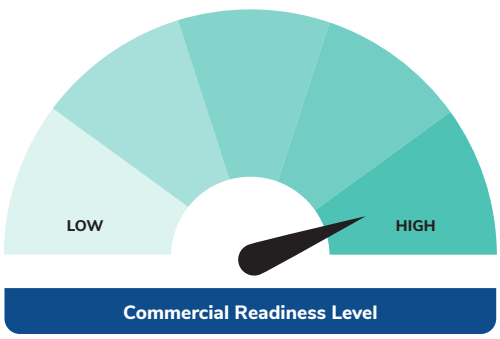
With the rise in molecular data volumes, AI-based diagnostics are emerging as tools to discover and detect disease signatures from ctDNA which manual analysis may miss.

AI can also decipher unknown patterns from complex molecular data and understand phenotypic and genotypic heterogeneity in individuals. The integration of AI into liquid biopsies has had a huge impact on diagnostics. Most new liquid biopsies now incorporate probabilistic modeling and deep neural networking in their workflow.

Compared to other molecular diagnostic tests, the penetration of AI in liquid biopsy solutions is high. There is a number of commercially available tests available with vendors including Delfi, Cancer Genomics and Freenome. Overall, more than 20 MDx companies currently use AI and/or Machine Learning (ML) in their liquid biopsy solutions. Over the last few years, many of these start-ups have captured the attention of the international investment community.

The *commercial readiness* of AI in liquid biopsies is **high**.

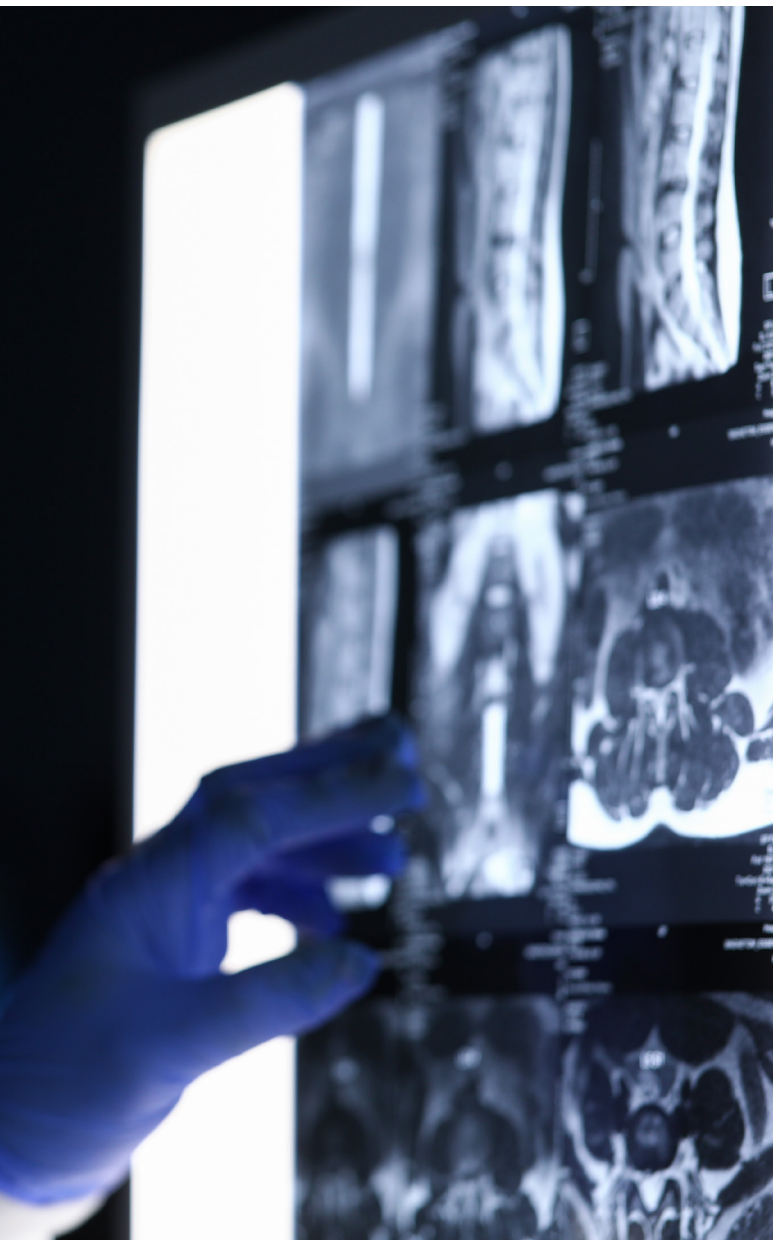
COMMERCIAL READINESS OF AI IN ONCOLOGY DIAGNOSTICS



Source: Frost & Sullivan

Predecine (US) is a leader in the field and has developed a Machine Learning-enabled GeneRADAR platform which allows sensitive cancer detection

The company's liquid biopsy solution detects both circulating free DNA and RNA (cfDNA and cfRNA) from blood or urine, enabling deep insights into the genomics and providing comprehensive cancer profiles. By adding RNA analysis, GeneRADAR moves diagnosis forward and can identify and provide information on alterations missed at the DNA level. Predecine's test is powered by the DeepSEA ML platform.



In the longer term, AI-powered molecular diagnostics is expected to pave the way to the development and provision of precision medicine

With the advent of precision medicine and the advance of next generation sequencing, the genomic profiles of patients have increasingly been used for risk prediction, patient stratification and the development of targeted therapies.

AI-based predictive algorithms for cancer, neurology and cardiovascular diseases have shown promising results, forecasting disease risk and therapeutic outcomes with a higher degree of precision than conventional techniques.

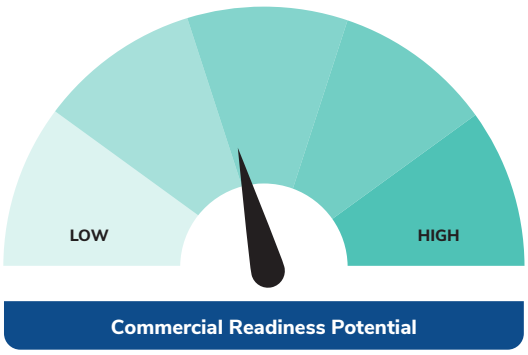
New platforms are usually trained on thousands of cancer-positive blood samples which enables multiomics solutions to identify and "learn" biomarker patterns and signatures specific to a cancer type and predict their responsiveness to certain treatments.

There are currently relatively few companies globally actively working with AI in their diagnostic workflows for precision and personalized medicine.

The main focus areas are oncology and neurological diseases.

The *commercial readiness* of AI in precision medicine is **medium**.

COMMERCIAL READINESS OF AI IN PRECISION MEDICINE



Source: Frost & Sullivan

PrediGen (US) is at the cutting edge of this area and is leveraging algorithms for the pre-symptomatic detection of viral/bacterial infections

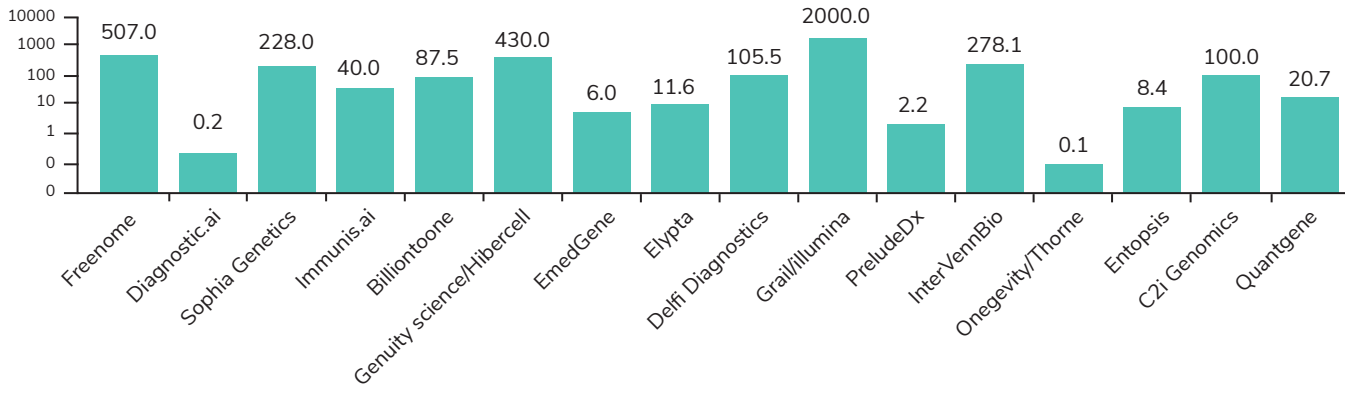
The company is developing an array of host response diagnostic assays, building on its experience in predictive genomics and advanced ML algorithms. Its efforts have resulted in an advanced portfolio for infectious disease testing.

PrediGen's key solutions are for the pre-symptomatic detection of viral and bacterial infections (Predigen PreV) and for tests to accurately discriminate viral from bacterial infections (Predigen B/V). Widespread adoption of these tests would enable early treatment initiation and also allow the use of appropriate therapeutics.

In six years, funding for AI-based molecular diagnostics has exceeded $3b

The majority of this in both volume and value terms stems from Private Equity firms with M&A within the industry a distant second followed by VC investment.

FUNDING FOR AI-BASED MOLECULAR DIAGNOSTIC COMPANIES, GLOBAL, JAN 2016-SEPT 2021



Source: Frost & Sullivan

In the future, assay-agnostic flexible AI analytics platforms are set to unleash further potential by democratizing and decentralizing molecular testing

One of the biggest challenges in molecular diagnostics is the availability of reliable analytics tools which can decipher the results of genomic tests. There is a pressing need to develop platform technologies that can be utilized for a variety of solutions and therefore reduce the challenges associated with analysis.

Many nations and regions, including India, Singapore, China and the EU, are also bound by stringent data privacy laws that prevent patient data or samples from leaving the country for analysis. This in turn calls for the development of software which can be used by labs across the globe to extract data and provide insights based on off-the-shelf chemistry.

Market participants therefore have an opportunity to develop AI tools which can be hosted on the cloud and utilized by laboratories performing molecular diagnostics wherever they may be. This would help decentralize the prevailing testing and analysis scenario and make it more accessible to all. It would also deliver reliable tools to resource-limited settings.

Companies such as C2i Genomics (US) and Sophia Genetics (Switzerland) are responding to this need and building scalable software and analytics tools which would be able to be deployed by diagnostic centers globally. The latter has partnered with GE Healthcare and Hitachi to reshape data driven medicine.

The *tissue diagnostics* segment is similarly being shaped by innovation with analysis of samples in laboratories becoming more precise and automated

In TDx, samples are stained with dyes or markers and observed under a microscope to assess cell abnormalities. This procedure uses three different techniques, including:

- The **preanalytical staining** process in which tissues are stained using H&E;
- **Advanced staining** which uses more precise methods such as ISH, IHC and special stains (SS); and
- **Anatomical Pathology Lab Information Management Systems** (APLIS) which manage these laboratory processes

The market has gained importance in recent years because of the need for personalized medicine, especially in oncology. Tissues are collected and analyzed based on a standardized protocol, followed by storage in specific conditions to retain their quality.

Source: Frost & Sullivan

Preanalytical staining techniques remain a cornerstone of the market with global sales of $2.6b in 2020 but lack reliability and upgradability

The **preanalytical staining** segment was valued at $2.0b in 2020 and is growing at a Compound Annual Growth Rate (CAGR) of 5.6%. The temporary suspension of non-COVID-19 tests caused a temporary decrease in growth but the short- and medium-term outlook is positive as the backlog of testing for other diseases has resumed. Revenues from preanalytical staining will are expected to decrease slightly in the longer term due to the preference for new technologies.

Even as the advanced stains segment gains momentum, H&E methods are continuing to drive preanalytical sales as they are still considered to be the gold standard in pathological interpretation. In addition, these techniques indicate underlying tissue morphology that allows the pathologist to analyze advanced stains correctly.

On the negative side, the preanalytical methodology that covers tissue collection and handling, analysis, preparation, processing and storage are comparatively uncontrolled, inconsistent and non-standardized which causes challenges with interpretation. Poor tissue sampling in the preanalytical segment is collectively responsible for approximately three-quarters of errors detected in diagnostic laboratories.

In 2019, PHC Group (Japan) acquired Thermo Fisher's (US) anatomical pathology portfolio, which includes its preanalytical staining solutions, and set up a new venture called Epredia. The company's precision cancer diagnostics solutions include tissue processors, microtomes and cryostats as well as immunohistochemistry products.

With reimbursement cuts amounting to 9% for pathology and 5% for independent laboratories in the US, the ability of manufacturers to make a return on their products and investments is expected to impact levels of innovation over time. A lack of technology upgrades will impact demand and is one of the reasons why preanalytical staining lacks the same strong price-to-performance ratios as advanced.

However, advanced staining techniques which offer personalized diagnoses continue to gain ground and now represent 58% of revenues

The **advanced staining** segment will register sales of $5.5b in 2025, up from $3.4b in 2020. As with pre-analytical staining, reimbursement cuts could affect the space, especially as the offerings are expensive compared to conventional forms of testing and the public financing that is available may not be sufficient to cover the cost of the additional reagents and labor that are required. Major players are therefore integrating automation into their offerings to compete with other more cost-effective technologies.

Heightened demand for ISH and IHC staining systems in 2021 and into 2022 was attributed to non-COVID-19 diagnostic tests resuming post-pandemic. These techniques have been rapidly adopted because they consume less time, produce fewer errors and reduce laboratory expenditure compared to pre-analytical staining.

ISH testing in particular is driving revenue growth in the advanced staining segment as it has become the preferred method for breast cancer diagnosis and is more accurate than IHC. Nonetheless, there is a growing focus on co-developing IHC assays with CDx solutions which is continuing to gain impetus. Companies such as Novodiax (US) are playing in this technology area although its application is currently limited to R&D.

CDx-based offerings that provide personalized care, automated services and faster turnarounds have increased, especially in North America and Europe. Players like Roche (Switzerland) have been leading the way here. The company received US FDA approval for its Ventana HER2 Dual ISH DNA Probe Cocktail assay in 2020. The solution provides clinicians with outcomes within the same day and therefore enables quicker therapeutic decision making. Overall, there are more than 40 similar CDx products currently on the market which are witnessing rapid adoption from laboratories. They are collectively expected to attract and receive significant investments from both the public and private sectors which will help to drive further technological advances and innovation.

Anatomical Pathology Lab Information Management Systems manage both of these processes and are growing rapidly at 10.6%

The **APLIS** segment will generate $789.4m in 2025 and account for 9% of revenues.

Customers' preference for Anatomical Pathology Lab Information Management Systems has increased because they can easily be integrated into existing laboratories and are compatible with equipment required for TDx testing. Adoption in Europe in particular is high because of a workforce shortage in the region as well as the relaxation of European Medicines Agency regulations concerning digitalization.

APLIS are off-the-shelf solutions for optimized data management. Their use improves processes, increases efficiency and supports patient safety by enabling traceability. For the integration of Laboratory Information Systems (LIS) cloud-based storage is preferred over server-based storage as it allows providers to conduct maintenance and upgrades remotely while the storage capacity is adjustable and secure thanks to encryption algorithms.

Vendors such as Xifin and Sunquest (both US) help laboratories to perform multiple tests on a single platform using multi-entity architecture-based LIS. Their solutions enable the optimization of the operational and clinical requirements of testing organizations. Laboratories with multiple departments prefer – and are able to deploy – multi-site offerings which provide interoperability within their facilities.

Moving forwards, APLIS systems that enable automatic report submission in a portable document format to Electronic Medical Records (EMRs) will attract customers. Sharing testing outcomes with clinicians directly after receiving pathologist approval will increase productivity and improve diagnostic pathways. NovoPath and Orchard Software (both US) are examples of LIS providers which are working towards streamlining these and other processes.

Source: Frost & Sullivan

From a supplier perspective, Roche (Switzerland) leads the way and is well positioned with solutions which address the market hotspots

Overall, Roche is the largest participants in the TDx market, accounting for a 23.7% share in revenue terms in 2020. The company has benefited from high demand for advanced instruments and CDx solutions which has caused sales for its tissue diagnostics division to increase, despite the fall off in volumes during COVID.

From a geographical perspective, the Asia-Pacific region has supported growth with strong sales of reagents while, in 2021, Roche expanded its footprint in Arizona (US) and established a 60,000 square foot facility dedicated to cancer diagnostic offerings.

Apart from Roche, Leica Biosystems and Dako, which is part of Agilent (all US), have the broadest geographical footprint and have been collaborating to offer holistic automated products and services. In 2020, Leica Biosystems and Bio-Techne (US) launched a CE-IVD marked RNAscope ISH kit to offer automation in their BOND-III platform in Europe.

Other key players are Sakura, Merck, Abbott and Biocare.

The company is working with GSK (UK) to develop Companion Diagnostic (CDx) tests with partnerships with biopharma considered to be best practice

Diagnostic companies are focusing on CDx-specific partnerships to develop personalized treatment for cancer and motivate patient-specific clinical decisions. In 2020, the US FDA reinforced this trend by releasing a document stating that CDx should be considered in the early stages of drug development and CDx-based products should be co-developed.

CDx companies are developing IHC assays, including biomarker expression, specimen types, antibody selection, clinical validation and assay protocols as CDx-based solutions while biopharma companies' efforts are focused on improving the predictive power of CDx offerings and developing personalized medicine, beyond cancer.

Roche and GlaxoSmithKline, for example, collaborated to develop a CDx-based IHC predictive test for endometrial cancer and received FDA approval for this during 2021.

In the future, best practice will include biopharmaceutical companies collaborating with well-established diagnostic companies that have experience in the CDx space to enable faster product development and regulatory approvals for specific disease areas. These partnerships should also reduce commercial risk.

In parallel, companies should focus on integrating CDx with IHC staining and Enzyme-linked Immunosorbent Assay (ELISA) testing as the latter enables better reproducibility and is easily quantifiable. In addition to developing a cytology test protocol, this methodology will also provide IHC results using frozen tissue within 10 minutes.

Source: Frost & Sullivan

Other opportunities include extending beyond oncology to enable TDx adoption …

TDx is currently cancer-centric and has fewer applications in metabolic and blood disorders than other diagnostic techniques due to a lack of regulatory approvals.

Developments outside oncology have also been slowed by companies' inappropriate planning which has delayed providing the right treatment to patients when needed. This has resulted in low adoption and lengthier processes for diagnostic tests within associated clinical guidelines. Reimbursements also remain variable and complex, making accurate economic evaluations difficult with systems for biomarker-based tests in particular needing differential pricing to enable innovation and faster adoption.

Nonetheless, non-neoplastic acquired conditions such as thalassemia, inflammatory bowel disease, malabsorption syndromes and GLUT-4 deficiencies associated with inherited lactose intolerance, offer growth opportunities for players in the TDx segment.

Formulating sophisticated market development strategies will enable faster commercialization and access to patients and become a key success factor for companies targeting these areas. Increasing pre-launch budgets to cover quality improvement strategies, training programs for physicians, payers and laboratories and marketing activities (such as product publications and direct-to-customer marketing) will raise awareness about their technology and boost adoption for disease diagnosis beyond cancer.

With experience, new technologies, faster regulatory approvals and partnerships with laboratories, TDx companies' products can be utilized more widely. Tie-ups with research and academic institutions could also enable early access to new innovations.

… and embracing Whole Slide Imaging technology to help caseload management

Whole Slide Imaging (WSI) is increasingly being implemented in tissue diagnostics because it digitally converts entire glass slides into virtual slides. This, together with the application of AI and computer vision, enables more slides to be reviewed in less time.

Small- and mid-sized laboratories have low digitalization adoption rates because of the large capital expenditure involved. Overall, however, investments in automation and subsequently competition has increased. Companies such as Paige.AI, PathAI and Volastra (all US) have received funding to focus on products catering to the preclinical market.

Moving forward, for the market to really take off, WSI providers will need to address small- and mid-sized laboratories with a solution that automates processes in their facilities at an attractive price point. In addition, vendors should provide easily deployable cloud-based solutions to these laboratories which can be incorporated into their existing systems while OEMs should explore developing independent reporting algorithms which identify tissues and produce automated reports without the help of a pathologist. AI-aided TDx diagnosis can be used for faster analysis of tumor grade, type, and extent, enabling quicker turnaround and automatic quantification of positive cells in WSI slides and their location.

Source: Frost & Sullivan

MURSLA

COMPANY **OVERVIEW**

Industry Segment:

Healthcare

Brief Description:

Mursla is developing a blood test to detect early-stage hepatocellular carcinoma

Maturity:

Under development

Multimedia:

https://www.youtube.com/watch?v=b0JoLTT9OPM

COMPANY **STRUCTURE**

FOUNDED: **2019**

COUNTRY: **UK**

OF EMPLOYEES: **10-15**

TOTAL FUNDING: **$750K**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- Mursla is developing a blood test to detect early-stage HepatoCellular Carcinoma – HCC. This process leverages a liquid biopsy, a non-invasive procedure, to detect specific markers leaked by the cancer tissue into the bloodstream.
- The company is developing ExoPheno, a platform exploiting a proprietary technology for the profiling of exosome phenotypes. ExoPheno leverages machine learning to merge together wet lab and dry lab analysis.
- The ultrasensitive nanochip technics under development combine a scalable nanoelectronics technology and a high-performance optical detection method.

Main competitive advantage

Mursla is developing a proprietary nanochip-based technology called ExoPheno to detect tissue-specific exosomes in blood. This technology allows ultrasensitive detection of exosomes and their markers in blood. The technology has several applications in different biomedical fields. The non-invasive detection is scalable and compatible with actual clinical practices.

Value Proposition

- Mursla is committed to improving diagnostic solutions through the biological analysis of exosomes. This process enhances the predictive power of liquid biopsies and enables an improvement in early-stage cancer detection.
- Mursla is developing a device that leverages a proprietary nanostructure to simplifies the whole cycle of cancer management.

Source: Frost & Sullivan, MURSLA

SEPTEC

COMPANY **OVERVIEW**

Industry Segment:
In vitro diagnostics

Brief Description:
SepTec is developing a sepsis diagnostic device to detect pathogens in blood.

Maturity:
Under development

Multimedia:
https://www.youtube.com/watch?v=huiWO-lSs70

COMPANY **STRUCTURE**

FOUNDED: **2020**

COUNTRY: **IRELAND**

OF EMPLOYEES: **5-10**

TOTAL FUNDING: **€2,4M**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- SepTec has developed a diagnostic device to detect pathogens in a suspected sepsis patient. The diagnostic devices detect both fungal infections and common viral bacteria.
- The patent-pending technology merges together smart microfluidic engineering and sensor technology. The technology under development enables a rapid capture and detection of a low number of cells in less than 15 minutes.
- The device is a microfluid disc preloaded with reagents in which to insert a vial of blood. The microfluid disc is fully automated.

Main competitive advantage

SepTec is developing a technology to detect pathogens without the need for blood culture or PCR amplification. The diagnostic device detects pathogens present in a suspected sepsis patient in less than 15 minutes.
The diagnosis of infection detected in the bloodstream is transmitted directly to the patient's point of care.

Value Proposition

- SepTec aims at reducing septicemia deaths by developing faster and more effective sepsis diagnostics. The company aims at supporting doctors by providing the right information in time, to increase the chances of survival for seriously ill patients.
- The company is committed to reducing the length of hospital stay and consequently reducing sepsis associated healthcare costs for structures.

Source: Frost & Sullivan, SEPTEC

VALAR LABS

COMPANY **OVERVIEW**

Industry Segment:

In vitro diagnostics

Brief Description:

Valar Labs leverages Artificial Intelligence to assist oncologists in making data-driven decisions.

Maturity:

Under development

Multimedia:

N.A

COMPANY **STRUCTURE**

FOUNDED: **2021**

COUNTRY: **USA**

OF EMPLOYEES: **10-15**

TOTAL FUNDING: **$4M**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- Valar Labs is developing a digital pathology vision tool based on Artificial Intelligence - AI. The tool under development will help oncologists make data-driven decisions. The AI will provide reliable and actionable insights.
- The company is developing a clinical deep-learning system to monitor the parameters of cancer patients. Each patient's characteristics are collected, stored, and analysed aiming at providing tailored results.

Main competitive advantage

Valar Labs leverages Artificial Intelligence - AI and clinical deep learning to help oncologists analyze each patient to make data-driven therapeutic decisions. The AI provides actionable data and insights. Leveraging artificial intelligence Valar Labs minimizes decision-making errors in cancer patients.

Value Proposition

- Valar Labs is committed to reducing uncertainty in decision-making oncology. The company aims at improving treatment for cancer patients through a data-driven process. The data-driven process aims at increasing the chances of recovery among cancer patients.
- The company aims at improving decision-making in cancer care to reduce the costs of treating cancer patients while boosting the effectiveness of treatments.

Source: Frost & Sullivan, VALAR LABS

BIOFIDELITY

COMPANY **OVERVIEW**

Industry Segment:

In vitro diagnostics

Brief Description:

Biofidelity has developed a molecular test to enable a fast and cost-effective early detection of various diseases.

Maturity:

Commercialization currently

Multimedia:

N.A

COMPANY **STRUCTURE**

FOUNDED: **2019**

COUNTRY: **UK**

OF EMPLOYEES: **50-100**

TOTAL FUNDING: **$36.6M**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- Biofidelity has developed a molecular test based on proprietary biochemistry called Allele-Specific PYrophosphorolysis REaction – ASPYRE.
- ASPYRE is a molecular diagnostic technology that boosts the detection of genomic biomarkers. The technology was developed to run on pre-existing PCR machines, the same instrumentation used for the COVID-19 tests.
- ASPYRE's technology is an enzymatic reaction called pyrophosphorolysis or reverse polymerisation of DNA. The chemical reaction activates a synthetic probe only when a target mutated molecule is present in a patient sample, enabling the probe to then be amplified and detected.

Main competitive advantage

Biofidelity has developed a molecular test based on proprietary biochemistry to enable the detection of genetic mutations from tissue or blood samples, without the need to sequence DNA. The company's molecular tests are scalable, allowing adaptation to routine applications. The ultra-sensitive molecular test is faster and more cost-effective, compared to other Polymerase Chain Reaction - PCR tests and Next Generation Sequencing - NGS tests.

Value Proposition

- Biofidelity is committed to improving the early diagnosis of diseases. High-sensitivity molecular tests developed aim at improving patient outcomes. The information generated through ASPYRE is intended to help doctors identify patients who can benefit from precision-targeted cancer therapies to reduce cancer deaths.
- The company aims at developing faster and more cost-effective molecular tests, compared to other Polymerase Chain Reaction - PCR tests and Next Generation Sequencing - NGS tests.

Source: Frost & Sullivan, BIOFIDELITY

NOSTOS GENOMICS

COMPANY **OVERVIEW**

Industry Segment:

In vitro diagnostics

Brief Description:

Nostos Genomics has developed an AI-based platform to identify multiple diseases

Maturity:

Commercialization currently

Multimedia:

https://www.youtube.com/watch?v=Fms6Fu92ONA

COMPANY **STRUCTURE**

FOUNDED: **2018**

COUNTRY: **GERMANY**

OF EMPLOYEES: **25-50**

TOTAL FUNDING: **$5,7M**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- Nostos Genomics has developed AION, an Artificial Intelligence – AI based platform capable of identifying gene variants of multiple diseases. AION platform identifies variants of diseases and provides an interpretation.
- The platform developed merges together synthetic biology knowledge and machine learning to automate the interpretation of results.
- Nostos Genomics' solution is fully automated and delivers accurate results. The platform provides a comprehensive report, downloadable as a normal PDF or CSV file or via the company API.

Main competitive advantage

Nostos Genomics has developed AION, a platform to identify gene variants of multiple diseases. The platform combines synthetic biology knowledge and machine learning to automate the interpretation of results. The AI-based platform AION reduces diagnosis time and costs: the exome interpretation can be performed in 2 minutes circa (instead of the 12 hours required by previous technology).

Value Proposition

- Nostos Genomics is committed to providing a fast and clear diagnosis to identify multiple diseases. This approach has been designed to reduce the possibility of misdiagnosis. The technology will help people living with a rare genetic disease that could be difficult to diagnose.
- The company aims at exploiting the AI-based technology to reduce time in the interpretation of mutations in genetic tests and providing an efficient diagnosis.

Source: Frost & Sullivan, NOSTOS GENOMICS

WOUND DIAGNOSTICS

As with in vitro solutions, conventional *wound diagnostics* and monitoring methods have their limitations and market participants are seeking alternatives

The accurate diagnosis of the microbial burden in wounds, assessment of their dimensions and monitoring of their healing as well as the documentation of this information are integral parts of wound care while the data obtained from these processes helps clinicians and healthcare workers evaluate the effectiveness of treatment regimens and to make suitable adjustments to maximize wound healing.

Traditional tools used for wound diagnosis and monitoring include ruler-based, wound tracing and biochemical analysis methods.

Each has its restrictions notably in terms of inaccuracy, discomfort and delay.

Ruler-based methods involve the use of disposable paper rulers for assessing a wound area by measuring its longest length and its perpendicular width.

These methods have shown to overestimate wound areas by up to 44%, especially in cases that have irregular edges and/or wrap around the body meaning that it is extremely challenging to make an accurate calculation. Health professionals must physically probe the wound to obtain reliable measurements which can cause patients pain.

Wound tracing methods involve placing transparent sheets on patients' wounds and tracing their borders to allow clinicians to compare wound areas from week to week. The method can be uncomfortable for patients while the accurate tracing of non-viable tissues and discoloration in the wounds can be challenging.

Biochemical analysis methods involve using swab tests to determine the state of wounds. However, these tests typically require days or even weeks to produce results during which time the condition of the wounds can often change significantly.

This is particularly true in the context of the growing burden of chronic wounds

The burden of chronic wounds on the global healthcare system has grown considerably in recent years owing to a sharp increase in the incidence of diabetes and obesity and an aging population. Chronic wounds include pressure ulcers, diabetic foot ulcers and venous ulcers all of which take a long time to heal and often involve complications. Delayed wound healing and associated challenges have a significant impact on patients and the healthcare system alike, increasing treatment costs and mortality rates.

Chronic wound diagnosis and care is estimated to account for between 1% and 3% of total healthcare expenditure in developed countries.

The total annual cost of hospital-acquired staged pressure ulcers to healthcare systems is approximately $26.8b while, globally, the annual incidence of diabetic foot ulcers ranges from 2% to 5%. The latter shows a 5-year mortality rate of 30.5% which is significantly higher than that for Charcot neuroarthropathy and breast cancer. Venous ulcers are estimated to affect around 3% of the adult population worldwide.

Source: Frost & Sullivan

The application of new advanced technologies brings the promise of greater accuracy, standardization and affordability and reduced patient discomfort

There is a growing acceptance among healthcare professionals of novel wound diagnosis and monitoring tools that use advanced technologies such as hyperspectral, multispectral, fluorescence and thermal imaging as well as biocapacitance, biosensors and AI all of which can help in overcoming the limitations of traditional methods.

Their use allows doctors and other healthcare workers to precisely and instantly diagnose the state of a wound and the type and levels of microbes within it while automation of the process reduces inaccuracies and inconsistencies in recording objective wound parameters including length, width, volume, depth and perimeter. At the same time, the cost of ownership is minimal for modern tools which trained health professionals can operate with ease and non-invasive methods serve to eliminate discomfort caused to the patients.

In particular, next generation computing, imaging and sensing is being applied …

Groups	Types	Applications
Computing	• AI including ML, Deep Learning (DL) and computer vision algorithms	• Hand-held scanners and smartphone- and tablet-compatible applications for digital wound assessment
Imaging	• Hyperspectral, multispectral, fluorescence and thermal imaging	• Hand-held scanners and portable screening devices
Biosensors	• PH, moisture, temperature, pressure and motion sensors	• Skin patches, mattresses and insoles

… notably in the domains of digital wound assessment and hand-held scanners

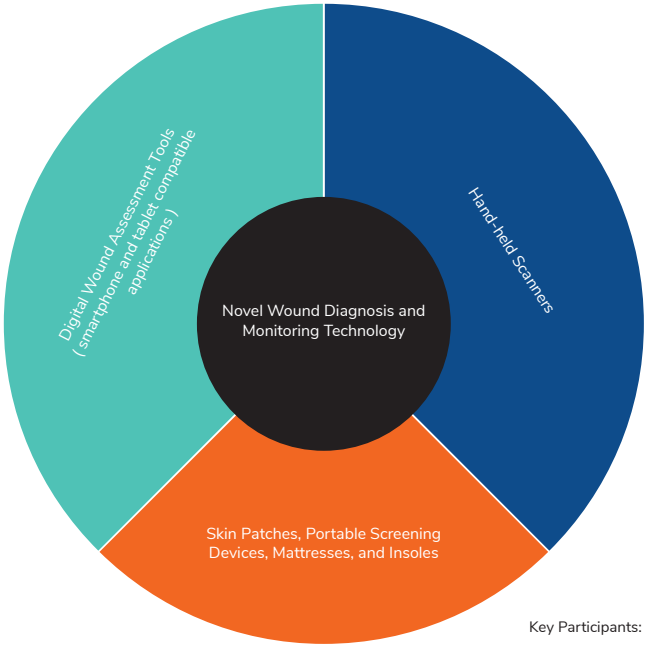
Digital wound assessment tools include smartphone- and tablet-compatible applications that can perform automated wound measurements and documentation. Key participants here are Swift Medical, Healthy.io, eKare, Perceptive Solutions, Tissue Analytics or SCARLETRED.

Hand-held scanners and portable screening devices that enable the capture of a wound's dimensions and other structural parameters. Key participants here are Adiuvo Diagnostics, MolecuLight, HyperMed Imaging, KroniKare or Bruin Biometrics.

Skin patches, mattresses and insoles devices help facilitate continuous and remote monitoring of wound healing progress and foot plantar pressure in patients and identify those individuals at high risk of developing chronic wounds. Key participants here are Orpyx Medical Technologies, Podimetrics, XSENSOR, Ayati Devices. Grapheal or Bluedrop Medical.

Source: Frost & Sullivan

APPLICATION OF ADVANCED TECHNOLOGIES IN WOUND MONITORING AND DIAGNOSIS, GLOBAL, 2022



Key Participants:

Digital wound assessment tools leverage AI, ML and computer vision to minimize clinic visits and accelerate wound documentation

Minimizing clinic visits

Smartphone- and tablet-compatible applications allow patients to easily capture and share high-precision and scientifically calibrated wound images with their caregivers from the comfort of their homes. They help reduce unnecessary travel for in-person hospital and clinic visits. For healthcare providers, digital wound assessment tools offer a cost-effective remote measurement solution. They reduce the risk of disease transmission, which became particularly important during the pandemic, and ensure continuity of care even in conditions where hospital or health center visits are not possible or too risky.

Accelerating wound documentation

The latest applications include features like autofill which automatically enters patients' wound measurements and tissue types. The data collected auto-generates a clinical summary about the wound. This significantly speeds up wound documentation tasks for health professionals, allowing them more time to provide patient-centered care. Access to comprehensive wound relevant information also facilitates informed treatment decisions.

Healthy.io (Israel) has developed a smartphone app which uses proprietary algorithms to measure wounds and evaluate their progress

Healthy.io's "*Minuteful* for Wound" app is used by **Leicestershire Partnership National Health Service (NHS) Trust** in the United Kingdom.

The Trust, a provider of community health services, was seeking solutions for precise wound measurement and improved patient engagement. It collaborated with Healthy.io to deploy the latter's smartphone-compatible application which uses proprietary algorithms to accurately capture wounds and analyze their progress. The use of the app by the clinicians decreased the variability when taking wound measurements. Furthermore, healthcare professions were able to leverage the system to show patients changes in their wound area after every session which helped them engage in their care and positively impacted their well-being.

Source: Frost & Sullivan

Swift Medical's (Canada) *"Swift Skin and Wound"* app is used by **Home and Community Care Support Service** in Canada**.**

The Service was looking to support the health providers in its network with remote monitoring capabilities for patients' wounds amid the COVID-19 pandemic. In February 2021, Home and Community Care Support Services deployed Swift Medical's app, a smartphone and tablet compatible application that leverages AI technologies to facilitate touchless wound measurement and visualization. The use of the app among interdisciplinary care teams in the Service enabled the caregivers to monitor patients' wounds remotely. This allowed accessibility to wound care for patients in their homes and, in turn, helped to decrease the number of in-person visits to the healthcare providers.

Hand-held scanners deploy hyperspectral, fluorescence and biocapacitance technology to detect pathogens and help healing

Detecting pathogens

Hand-held scanners can accurately detect the signs and symptoms of infection on both the surface and the deeper parts of a wound. They can also precisely identify the concentration and types of microbes present in the wound site including Pseudomonas aeruginosa, Escherichia coli, Staphylococcus aureus, Bacteroides fragilis and Clostridium perfringens. The objective assessment of wound infection levels and a clear understanding of the types of pathogens present can facilitate the selection of appropriate antibiotics, help prevent the development of microbial resistance and decrease the cost of treatment.

Helping healing

The ability of the scanners to diagnose the microbial load in the wounds allows healthcare professionals to conduct sampling and debridement processes, targeting wound areas with the significant concentration of pathogens. This, in turn, accelerates endogenous healing in the wounds and subsequently improves health outcomes for the patients.

Adiuvo Diagnostics (India) provides a device that takes hyperspectral images to identify infection and measure wound width, length and area

Adiuvo Diagnostics' "*Illuminate*" scanner is used by the **Dr. D Y Patil Medical College, Hospital and Research Centre** in India.

The Centre was seeking solutions for the quicker detection of microorganisms in patients' wounds. According to the research conducted by the facility and published in February 2020, the deployment of Adiuvo Diagnostics' Illuminate scanner enabled accurate identification and classification of all pathogens within two minutes. This eliminated the need for conducting repeated wound swabs with the patients.

Smith + Nephew's (UK) "*MolecuLight i:X*" scanner is used by **Whipps Cross Hospital Podiatry Clinic** in the United Kingdom.

The Clinic was looking to support its wound care practitioners with making objective wound infection assessments and therefore to select the most appropriate antimicrobial dressings. According to a retrospective analysis of 229-foot ulcers conducted between 2018 and 2020, the MolecuLight i:X scanner enabled clinicians at Whipps Cross to correctly identify microorganisms in patients' wounds and prescribe effective pathogen-specific antibiotics. This was clearly demonstrated by a decrease in the overuse of drugs by 33% and a reduction in antimicrobial spending per wound of 47%.

Source: Frost & Sullivan

In the long-term, theranostic products represent the next frontier in wound care

Today, wearable skin patches capture patients' wound bed data and transmit the information to health professionals.

However, if any signs of clinical deterioration are observed in the wound site once the patient has been discharged, they have to visit a hospital or healthcare center so that health professionals can initiate medical interventions. This can cause delay in providing appropriate therapies and adversely impact the wound healing process.

There is therefore a need for tools that can monitor wound healing and deliver timely therapies to address the limitations of current wearable skin patches.

Wound care companies should collaborate with academic and research institutes to develop theranostic wound care products including "smart" wearable skin patches and bandages that promote rapid wound healing and track treatment responses without disturbing the wound.

Theranostic wound care products being developed by organizations such as the University of Glasgow (UK) and the University of Manitoba (Canada) use sensors, microprocessors and electrodes, power and control modules or drug carriers. The embedded sensors record biological parameters at the wound bed. The data is subsequently read by the microprocessors which then send signals to the electrodes and the power and control modules or drug carriers to initiate electrical stimulation or release drugs on demand. This reduces infection or disrupts the bacterial biofilm formed on the wound.

The ability of these emerging products to facilitate the delivery of therapies instantly and without human intervention can help hasten wound healing and improve health outcomes.

Source: Frost & Sullivan

EVOBIOTECH

COMPANY **OVERVIEW**

Industry Segment:

Wound diagnostics

Brief Description:

Evobiotech is developing a technology based on extracellular vesicles for repairing wounds

Maturity:

Under development

Multimedia:

N.A

COMPANY **STRUCTURE**

FOUNDED: **2019**

COUNTRY: **ITALY**

OF EMPLOYEES: **2-10**

TOTAL FUNDING: **€1M**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- EvoBiotech is developing advanced wound care therapies at preclinical and clinic level. The company exploits an innovative technology based on plant extracellular vesicles to develop a line of natural products that promote wound regeneration.
- EvoBiotech technology leverages antioxidant and regenerative properties of extracellular vesicles to accelerate wound repair.
- Extracellular vesicles are bioactive nanoparticles composed of proteins, lipids, and nucleic acids. The extracellular vesicles send information from the donor cell to the recipient cell. This process promotes tissue regeneration and activates regenerative programs.

Main competitive advantage

EvoBiotech is developing a patented technology based on the antioxidant and regenerative properties of extracellular vesicles. Compared to technologies currently on the market, EvoBiotech's solution shortens the healing time of chronic wounds and prevents infections.

Value Proposition

- EvoBiotech is committed to reducing wound recovery time to improve the quality in the life of chronic wound patients. EvoBiotech is also committed to preventing infections from chronic wounds.
- The company intends to evolve regenerative medicine through the usage of therapeutic properties of extracellular plant vesicles. The company aims at reducing the medical costs associated with the long healing times of chronic wounds.

Source: Frost & Sullivan, EVOBIOTECH

GRAPHEAL

COMPANY **OVERVIEW**

Industry Segment:

Wound diagnostics

Brief Description:

Grapheal is developing graphene-based biosensors to improve chronic wounds medical care and diagnostic tests

Maturity:

Under development

Multimedia:

https://vimeo.com/640529877/e642417789

COMPANY **STRUCTURE**

FOUNDED: **2019**

COUNTRY: **FRANCE**

OF EMPLOYEES: **10-15**

TOTAL FUNDING: **$2,3M**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- Grapheal is developing a graphene-based biosensor for the diagnosis and monitoring of chronic wounds, including monitoring of wound healing and detection of infection. The digital biosensors are integrated into embedded systems such as test strips and patches.
- Grapheal is developing WoundLab, a wearable biosensor enabling real-time monitoring of wounds. The electronic wound patch automatically collects data in a medical cloud and sends real-time alerts directly to NFCs devices.

Main competitive advantage

Grapheal is developing graphene-based biosensors. The first product, called WoundLab, allows continuous monitoring of wounds via a smartphone app. The data are collected in real time into the cloud and can be used to check the evolution of the wound. The wearable biosensors allow doctors to monitor wounds remotely. WoundLab can alert the care givers in case of infections or complications. The Grapheal solutions leverage NFC technology and require no specific equipment.

Value Proposition

- Grapheal aims at improving chronic wounds medical care. The solution collects data automatically and enables remote wound control, improving the quality of wound care and reducing recovery time. The remote control of wounds allows doctors and nurse aims at reducing costs for healthcare facilities.
- The company is also committed to simplifying and speeding up SARS-Cov-2 screening during the pandemic period. The TestNPass, a digital diagnostic test based on saliva to detect SARS-Cov-2 allows a 6x faster detection than the other solutions on the market. The digital test detects the presence of a virus via a smartphone or any NFC device.

Source: Frost & Sullivan, GRAPHEAL

KRONIKARE

COMPANY **OVERVIEW**

Industry Segment:

Wound diagnostics

Brief Description:

KroniKare is developing an AI-based technology for the management of chronic wounds

Maturity:

Under development

Multimedia:

https://www.youtube.com/watch?v=c_ZdYYxFQZs

COMPANY **STRUCTURE**

FOUNDED: **2017**

COUNTRY: **SINGAPORE**

OF EMPLOYEES: **20-50**

TOTAL FUNDING: **$55,9K**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- KroniKare is developing an AI-based technology for the management of chronic wounds. The technology uses the scanning device and evaluates the wound via the data embedded in the AI server.
- KroniKare Wound Scanner device is a portable multi-spectral scanner that merges Cloud Technology and Artificial Intelligence – AI for a fast scan of chronic wounds. AI technology automatically stores data and integrates it with 15 years of collection of other scientific data.
- KroniKare automatically generates a reporting dashboard once the chronic wound has been scanned and assessed by AI technology.

Main competitive advantage

KroniKare is developing an Artificial Intelligence – AI patented technology for chronic wound care, enabling accurate detections and quick scans for better decision-making. The AI technology is secure and scalable. The non-invasive technology enables a chronic wound scan 30 times faster than other technology on the market.

Value Proposition

- The company is committed to improving preventive care for wound management. The solution developed by KroniKare aims at reducing scanner fatigue, time, and manpower.
- KroniKare aims at strengthening clinical care and home care facilities by reducing costs related to wound management.

Source: Frost & Sullivan, KRONIKARE

NANOMEDIC

COMPANY **OVERVIEW**

Industry Segment:

Wound diagnostics

Brief Description:

Nanomedic is developing a portable electrospinning device for wound treatment

Maturity:

Commercialization currently

Multimedia:

https://www.youtube.com/watch?v=AJISm9sjM64

COMPANY **STRUCTURE**

FOUNDED: **2018**

COUNTRY: **ISRAEL**

OF EMPLOYEES: **10-20**

TOTAL FUNDING: **$9,51M**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- Nanomedic is developing Spincare, a portable electrospinning device for the treatment and management of wounds.
- The Spincare system prints a nano-fibrous skin layer that remains over the wound until the underlying skin is completely epithelialized. Spincare's nanofibrous matrix is biocompatible can be enhanced with various additives, such as collagen, embedded human cells, and antibacterial materials.
- The nanofibrous matrix is printed on the patient's wound in real time. The solution is applied at 20 cm distance without any contact between the patient and doctors.

Main competitive advantage

Nanomedic Technologies is developing a patented technology device for chronic wound management. Spincare is a portable electrospinning device for the treatment of wounds. Spincare's nanofibrous matrix provides a translucent protective barrier, which monitors the healing process and reduces the risk of infection. The solution is handheld and easy to use for several complex clinical applications. The Nanomedic solution is tailored for different size and different conditions of wound.

Value Proposition

- Nanomedic aims at reducing pain and medical complications while increasing wound healing quality.
- Nanomedic is committed to reducing wound recovery time to improve the quality of life of chronic wound patients. Nanomedic is also committed to preventing infections from wounds.
- The company aims at reducing the medical costs associated with the long healing times of chronic wounds.

Source: Frost & Sullivan, NANOMEDIC

SOLASCURE

COMPANY **OVERVIEW**

Industry Segment:

Wound diagnostics

Brief Description:

SolasCure has developed a patented hydrogel technology to improve chronic wounds treatments.

Maturity:

Under development

Multimedia:

https://youtu.be/DZ_IoKDDp0c

COMPANY **STRUCTURE**

FOUNDED: **2017**

COUNTRY: **UK**

OF EMPLOYEES: **10-20**

TOTAL FUNDING: **$20,8M**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- The company has developed a semi-solid hydrogel formulation that provides a moist wound environment to activate autolytic debridement and to support wound healing.
- SolasCure has developed Aurase Wound Gel, a fibrinolytic hydrogel containing active enzymes obtained from specially bred medical maggots. Aurase provides an immediate fibrinolytic activity to the wound to speed up the debridement process.
- The enzyme is cloned and isolated from medical maggots. The SolasCure technology leverages the antimicrobial, anti-inflammatory and antibiofilm properties of small larvae.

Main competitive advantage

SolasCure is developing a patented technology to improve chronic wound treatments. The solution, called Aurase, is obtained from specially bred medical maggots. Compared to other enzymes-based solutions on the market, Aurase enables a specific activity against fibrin networks. Aurase hydrolyze fibrin-based debris without damaging healthy tissue or interfering with body's own autolytic processes.

Value Proposition

- SolasCure aims at providing care access for all and improving life in chronic wounds patients. The company is committed to preventing amputations and reducing death related to improperly treated wounds.
- The company is committed to supporting chronic wounds patients and healthcare professionals by reducing the time to achieve the full debridement of wounds.
- SolasCure aims at promoting biodiversity in clinical treatment.

Source: Frost & Sullivan, SOLASCURE

QUANTIQ

COMPANY **OVERVIEW**

Industry Segment:

Wound diagnostics

Brief Description:

Quantiq develops AI-based health monitoring solutions leveraging smartphones and webcams.

Maturity:

Under development

Multimedia:

N.A

COMPANY **STRUCTURE**

FOUNDED: **2020**

COUNTRY: **FRANCE**

OF EMPLOYEES: **10-20**

TOTAL FUNDING: **$2,86M**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- Quantiq is developing a technology that transforms smartphone cameras and webcams into a medical-grade device exploiting Artificial Intelligence – AI.
- The technology merges AI, physics, and advanced image processing to detect health parameters through a webcam or a smartphone camera. The AI leverages webcams and smartphones camera to detect respiratory frequency, heart rate, blood pressure and SpO2.
- The Quantiq technology is accessible both locally and as a Software-as-a-Service – SaaS.

Main competitive advantage

Quantiq is developing a contactless medical diagnosis technology. The company's technology leverages webcams or smartphones available to the patient for contactless detection of important vital parameters. The use of smartphones and webcams simplifies the patient examination procedure, making care management easier than the other solutions on the market.

Value Proposition

- The company aims at promoting telemedicine by making vital parameters available faster, reducing the costs of medical expenses.
- Quantiq is committed to improving the level of patient care by making the relationship between doctor and patient less complex.

Source: Frost & Sullivan, QUANTIQ

SWIFT MEDICAL

COMPANY **OVERVIEW**

Industry Segment:

Wound diagnostics

Brief Description:

Swift Medical has developed a digital wound care solution to improve prevention, treatment, and management of wounds.

Maturity:

Commercialization Currently

Multimedia:

https://www.youtube.com/watch?v=A-7MQ2brKpI

COMPANY **STRUCTURE**

FOUNDED: **2015**

COUNTRY: **CANADA**

OF EMPLOYEES: **51-200**

TOTAL FUNDING: **$ 47,1M**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- Swift Medical developed a powerful wound engagement tool for organizations across healthcare, transforming every aspect of healing from point of care to patient administration and analysis thanks to Point of Care Swift app (for patients) and Patient Admin Swift Dashboard (for clinicians).
- Swift Medical technology automatically captures wound length, width and surface area accurately thanks to HealX, FDA registered marker applied to calibrate each image captured with Swift App. Swift's AI analyses the wound and provides patient and wound specialists with a comprehensive view of specific wound care population and tracking the progress.
- Swift Dashboard is configurable on clinician's workflow, it is possible to define mandatory steps by customizing how nurses use the App and to drive consistent documentation and ensure accurate reporting.

Main competitive advantage

Swift Medical developed a digital wound care solution able to make the most impactful customer connections at the right time through real-time insights behaviour. Adopting Swift App and Swift Dashboard in a clinician workflow brings 300% faster healing rate, 88% reduction in pressure injury prevalence and 48% less time required per nurse visit. Swift technology also turns wound care success into a powerful marketing tool to attract more patients.

Value Proposition

- Swift Medical is proposing a leading-edge wound care management from bedside to back office, accurately designed with wound care experts for anyone to use.
- Swift Medical aims at reimagining health care technologies, providing a solution designed with deep empathy to enable new levels of clinical care.

Source: Frost & Sullivan, SWIFT MEDICAL


DIGITAL TWINS

In addition to AI, Digital Twins (DTs) represent a key emerging technology that will shape the diagnostics and broader healthcare space

Their use is being explored by a range of industry stakeholder including:

- Healthcare providers, e.g., to design clinical pathways
- Life science companies, e.g., to classify drug risks
- Diagnostics and device companies, e.g., to conduct clinical trials
- Customers (patients), e.g., to design health plans

DTs initially found their use in the production and engineering sectors but can now be usefully applied to humans, devices and hospitals

A Digital Twin is a simulated clone of a tangible item or an intangible system/process that users can study independent from its real-world counterpart to aid decision-making.

In healthcare, developers can create a DT for a human (or organ), device, and/or healthcare delivery center (e.g., hospital, clinic, surgery …).

Its key features are that it provides a digital representation which is virtual, dynamic, real-time (based on a two-way information flow) and modeled on various inputs/data sources.

Overall, Digital Twins in healthcare can enable proactive decision-making, process and cost optimization, risk prediction, better outcomes (e.g., precision medicine) and virtual care.

A *human* digital twin supports with the delivery of personalized healthcare

A **human DT** requires assorted and real-time information from a patient's records as well as wearables, diagnostic devices and other self-reported inputs outside the healthcare system. Access to a human DT can help healthcare providers understand how a patient responds to changing conditions, enable fully personalized care and support effective decision-making and the provision of timely recommendations.

DTs for entire human beings are still in development with their more widespread adoption being hindered by challenges in data collection. These include difficulties with capturing and onboarding longitudinal and multidimensional data as well as issues around information quality and accuracy which can have a negative on impact optimal disease monitoring and the timeliness of any diagnosis and treatment.

Human DTs can form a Digital Twin aggregate which can be beneficial for studying health at a population as well as a personal level. This has the potential to support public authorities with assessing health risks and creating effective health plans.

DigiTwins is a European flagship project with more than 200 partner organizations in 32 countries working which has awarded more than $1b in research funding over 10 years. The program is focused on the idea of the virtual patient and aims to develop truly personalized healthcare and prevention and to help move the industry toward value-based care.

Typical **human DT** value business value propositions include:

- *Understanding* individualized risk factors based on non-healthcare factors
- *Enabling* more accurate and rapid diagnosis
- *Predicting* responses to interventions, treatments and new drugs
- *Facilitating* fewer, faster and safer clinical trials
- *Optimizing* the operations of healthcare organizations

Source: Frost & Sullivan

For medical *devices*, DTs enable improved design and performance

A medical **device DT** is a virtual depiction which captures a device's physical properties, operational algorithms and environment. Embedded sensors and/or information from wearables are vital for making well-founded decision regarding patients' health and forming an accurate picture of a device's configuration, usage and maintenance history. The virtual depiction of a device stems from the measurement of vibrations, pressure, fluid levels, electrical voltage, environmental parameters and device performance metrics in real time.

Faulty physical and digital medical devices have the potential to be detrimental to patients and can generate high expenses. Regular monitoring helps to reduce these costs whilst predictive maintenance can maximize a device (and its parts') service life, optimize patient safety and result in efficient and safe device management.

Increasingly, Original Equipment Manufacturers (OEMs) are offering medical device DTs as-a-Service in order to provide maximum value to both healthcare providers and their patients.

Typical medical **device DT** value business value propositions include:

- ***Predicting*** and detecting quality defects
- ***Identifying*** products in the field that need maintenance or upgrades
- ***Improving*** manufacturing equipment design and usage
- ***Resolving*** warranty and claims issues and improving customer experience
- ***Reducing*** launch times

A *hospital* digital twin provides more dynamic operations and processes

A **hospital DT** simulates medical facilities or other healthcare institutions with complex structures and setups. A "virtual hospital" covers multiple resources to demonstrate how to optimize daily operations for increased workflow efficiency and safety. Simulations can be at a department level – e.g., for an Intensive Care Unit (ICU), radiology ward or patient waiting areas – or designed for specific operating or surgery units.

Healthcare facilities comprise specialized medical equipment, information technology infrastructure, labor forces and other miscellaneous business systems. Simulations from hospital digital twin support improved operations and processes through the provision of digital floor plans and equipment maps and via data which supports the deployment of more efficient logistics, staffing, administration and financial transactions.

Typical **hospital DT** value business value propositions include:

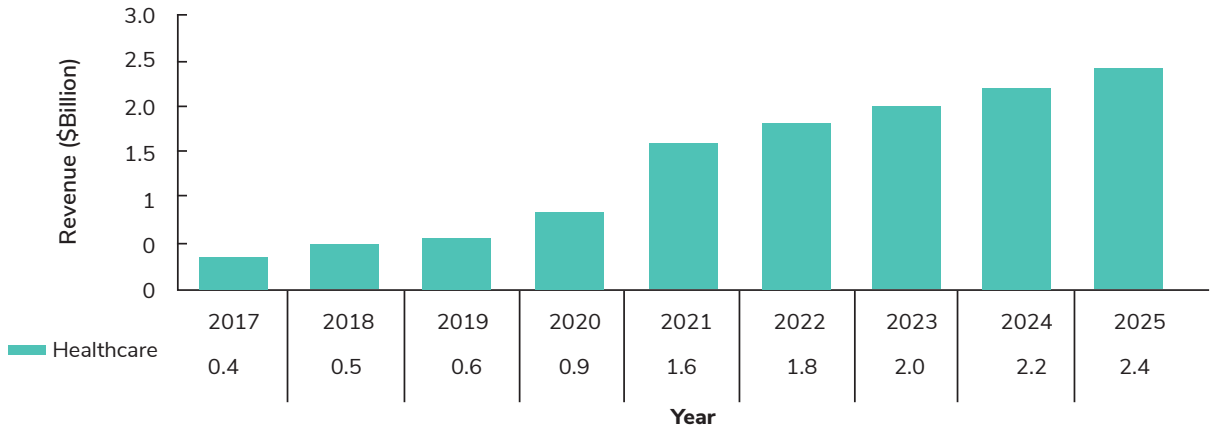
- ***Facilitating*** the advent of smart hospitals
- ***Increasing*** customer satisfaction and reducing staff burnout
- ***Visualizing*** patient journeys from arrival to departure
- ***Allocating*** resources more effectively and increasing operational flexibility
- ***Managing*** emergency situations safely

The market for DTs in healthcare remains nascent and sizing it can be challenging but Frost & Sullivan expects global revenues to reach $2.4b by 2025

Quantifying the revenue stemming from digital twins is complicated by the fact that much of the technology associated with them is also fundamental to the broader expanding area of healthcare data analysis. However, by examining the overall DT market leaders that provide solutions for healthcare applications, it is possible to gauge their overall reach and therefore to understand the shape and size of the opportunity.

On this basis, Frost & Sullivan expects sales of healthcare digital twins to reach $2.4b globally by 2025. This corresponds to around 13% of the overall DTs market.

DIGITAL TWINS IN HEALTHCARE MARKET, REVENUES, GLOBAL, 2017-2025



Growth will be aided by the fact that, unlike many other digital solutions, the impact of DTs can be quite easily quantified and assessed

A key criticism of applications designed to deliver "better" healthcare is that they simply load the clinical workflow rather than deliver any measurable improvement in treatments or outcomes. Digital Twins could easily be similarly perceived if rational metrics are not adopted to gauge their real impact in business and most importantly patient-centric terms.

It is fortunate that DTs, being highly dependent on metric collection, can also be a source of their own efficacy assessments.

Meaningful Key Performance Indicators (KPIs) can be built into the clinical workflow and can therefore be made available to clinicians. For example, for process improvement, a patient's time at a station and/or in transit from one care station to another can be collected simply by identifying when they enter or exit. This data can be collected by manually logging each patient in as they arrive and logging them out when they leave. Metrics like this can, however, also be collected automatically if the patient is issued with a locator badge on admission and compared to theoretical baselines or best practices.

Patient outcomes assessments can likewise be collected based on post-care reviews. If a patient has repeat visits for the same complaint, for example, an approach can be evaluated on whether and how well it was able lead to a successful outcome. Ultimately, a determination can be made as to whether a treatment is making a difference to overall results.

Overall, sufficient evidence to support the advantages of DTs is lacking as the technology is relatively new to healthcare, particularly when it comes to human or organ twins.

Source: Frost & Sullivan

Overall, healthcare executives and clinicians are increasingly recognizing the benefits of simulating physical assets which is translating into investment

According to researchers from the Cambridge Service Alliance (CSA) at the Institute for Manufacturing, University of Cambridge (UK), 25% of providers were considering procuring DT solutions in 2021 whilst 66% will make the move in the next 3 years.

This is a reflection of a growing understanding that virtual assets, processes and systems are viable solutions for improving clinical decision-making and operational efficiency whilst boosting quality control, performance and cost savings.

Strong investment from healthcare providers in Digital Twins is expected as they build their focus on preventative care and predictive maintenance. Funding will nearly triple over the coming years as the ROI becomes clearer through further deployments.

As interest grows on the demand side, DT vendors can benefit from working with buyers to identify the key areas where they will support digital transformation efforts.

This is to the benefit of an emerging vendor ecosystem which includes large equipment manufacturers and smaller firms focused on niche applications

The healthcare Digital Twin market is in its early stages and has shown strong growth since the COVID-19 pandemic hit in 2020.

Siemens Healthineers (Germany) is an example of a global OEM which plays into the space, competing with a range of start-ups.

Most vendor activity is focused on human DTs as players position themselves to enable virtual care in the personalized healthcare journey. In particular, cardiovascular and metabolic conditions are areas of intense activity as these diseases have high incidence rates and are burdensome to the healthcare sector.

Type of Digital Twin	Example Provider
Human	• Babylon, Sim&Cure, Siemens Healthineers, Unlearn, Biotwin, Q Bio, Virtonomy, Twin Health, Predisurge, Optimo Medical, Dassault Systemes, Philips, Nurea
Devices	• Hitachi, GE Healthcare
Hospital	• Verto Health

Source: Frost & Sullivan

An analysis of competitors strategies reveals that vendors with an integrated platform solution have an advantage when developing a Digital Twin.

The typical sales channel is business-to-business (B2B) with the as-a-Service (aaS) model taking root. Here, vendors position DTs as solutions that require (continuous) data accumulation, analysis and visualization on a real-time basis.

Medical device vendors are also increasingly offering DTs with sale of a physical device as an additional service which facilitates preventive maintenance.

Under all of these scenarios, the advent of Digital Twins is accelerating the transition of vendors from hardware OEMs to med-tech solution providers with service provision, in many guises, a core part of the strategy to obtain an edge.

DTs are in the early stages of development and companies must work with regulatory bodies to demonstrate proof of concept and, ultimately, concrete results for them to be able to play an active and effective role in shaping new clinical pathways.

Notable recent supplier developments include Siemens Healthineers working with a hospital in Ireland to simulate its patient workflow

Siemens Healthineers worked with **Mater Private Hospital**, a leading facility in Ireland, to upgrade its radiology department and to provide new efficiencies in care delivery. The company enabled the hospital to deliver greater patient value using a DT for workflow simulation. The Hospital's goal was to reduce wait times and delays.

Siemens Healthineers developed a human heart digital simulation using approximately 250 million images and reports. The DT allowed a greater understanding of cardiac conditions and enabled predictive care for underlying health issues. Siemens Healthineers brings medical-tech expertise and strong client relationships to bear and is able to leverage existing information from its systems to the benefit of its healthcare customers.

Babylon and **Bupa** have similarly collaborated on a pilot project to launch personalized DTs. The companies use AI and deep-learning technology to create a virtual model from a patient's medical history. The DTs are transparent human figures with identifiable organs which are available for viewing by clicking on each organ to access health and future risk information. Babylon Offers this service as part of its ***Healthcheck*** tool subscription.

Other developments include:

- **Q Bio's** launching a DT platform which comprehensively captures and monitors patients' baseline health in a scalable fashion. Its product, *Q Bio Gemini*, highlights physiology changes and provides a summary that physicians can access for action and treatment. The platform develops and provides a whole-body simulation in 15 minutes. Bio Gemini's uniqueness lies in its business-to-consumer model in which the company charges patients $3,495 for membership which includes a whole-body scan and an integrated telemedicine consultation

Source: Frost & Sullivan

- **Dassault Systèmes** showcasing a new solution at the Consumer Electronics Show 2022 where attendees could meet their virtual twin. Dassault created the experience using its ***3DEXPERIENCE*** platform and applications. The company strongly believes in the potential of DTs' for advancing research using augmented reality, in particular in respect of organs such as the heart and brain
- **Philips** developing a dynamic *HeartModel*, an automated, model-based ultrasound for left ventricular and atrium measurements which address the variability that is inherent in current clinical practice

Ultimately, success or otherwise will rest on suppliers' ability to increase quality and cut costs through interoperability and data integration

Interoperability is essential to achieving a successful Digital Twin. In addition, vendors will neem to develop strong partnerships with hospitals in order to fully understand healthcare providers' clinical, workflow and financial imperatives. Once a use case is identified and a DT solution developed, finding opportunities to scale with be vital.

Clinical trials represent a growth opportunity with DTs being deployed to accelerate drug discovery and development via digital modelling

Clinical trials are the most time-consuming and costly activity conducted by pharmaceutical companies with each drug on average requiring nearly 15 years of development and R&D expenditure reaching approximately $83b globally each year. Disease specificity as well as the drug type and constitution (amongst other issues) add to the complexity of the process while patient recruitment is becoming a growing concern.

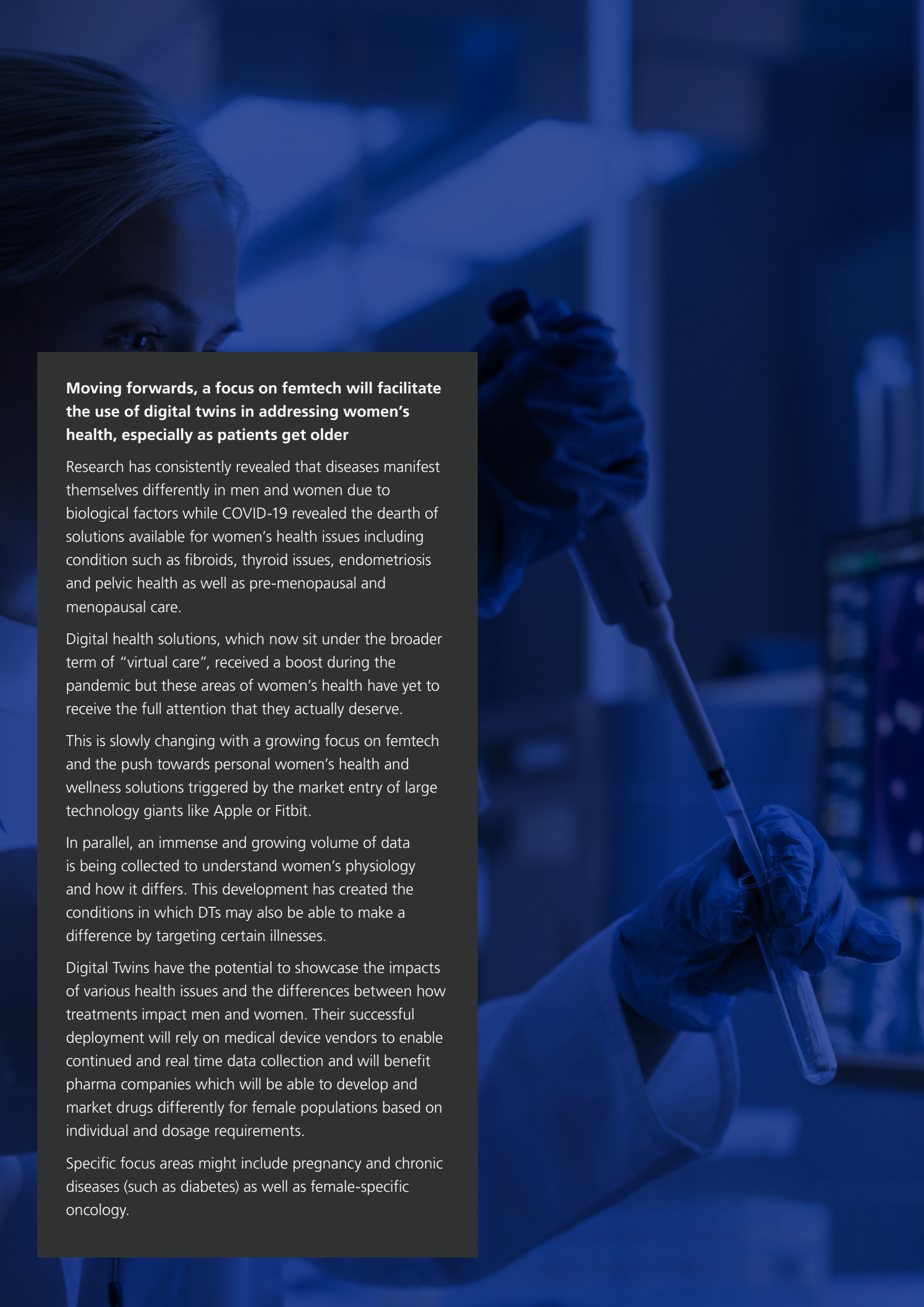
Unlearn.AI (US) is a start-up which is looking to address some of these challenges by offering a Digital Twin service which duplicates patient characteristics in trials in order to enable the use of a smaller sample size and to facilitate faster studies. The company raised $50m in a Series B funding round in April 2022 and hopes that DTs, AI and ML learning can accelerate drug discovery by first modeling their impacts before going to clinical trials.

Clinical trials have been a key target area for DT vendors such as Unlearn.AI as they aim to partner with pharma and biotech companies as well as academic research institutes to focus on certain "essential" drugs and reduce the associated cost of development.

In addition to reducing the time to market, Digital Twins are finding applications amongst pharma researchers in exploring the potential risks posed by drugs. This contributes to ensuring better safety of individual drugs and combinations.

Moving forward, pharma companies should identify specific areas where organizing clinical trials is a challenge and work with DT developers to find solutions to these. Digital Twin vendors could for example focus on early discovery stages to reduce resource wastage in Phases 2 and 3. Alternatively, concentrating on orphan drugs or rare diseases could help build credibility for DTs as these are niche areas that need lower patient numbers.

Source: Frost & Sullivan



Moving forwards, a focus on femtech will facilitate the use of digital twins in addressing women's health, especially as patients get older

Research has consistently revealed that diseases manifest themselves differently in men and women due to biological factors while COVID-19 revealed the dearth of solutions available for women's health issues including condition such as fibroids, thyroid issues, endometriosis and pelvic health as well as pre-menopausal and menopausal care.

Digital health solutions, which now sit under the broader term of "virtual care", received a boost during the pandemic but these areas of women's health have yet to receive the full attention that they actually deserve.

This is slowly changing with a growing focus on femtech and the push towards personal women's health and wellness solutions triggered by the market entry of large technology giants like Apple or Fitbit.

In parallel, an immense and growing volume of data is being collected to understand women's physiology and how it differs. This development has created the conditions in which DTs may also be able to make a difference by targeting certain illnesses.

Digital Twins have the potential to showcase the impacts of various health issues and the differences between how treatments impact men and women. Their successful deployment will rely on medical device vendors to enable continued and real time data collection and will benefit pharma companies which will be able to develop and market drugs differently for female populations based on individual and dosage requirements.

Specific focus areas might include pregnancy and chronic diseases (such as diabetes) as well as female-specific oncology.

PREDICTIV

COMPANY **OVERVIEW**

Industry Segment:

Digital twins

Brief Description:

Predictiv has developed the first DNA-based Digital Twin to identify the genetic predispositions for specific diseases and to simulate personalized reactions on drugs.

Maturity:

Commercialization Currently

Multimedia:

https://www.youtube.com/watch?v=GkIWnLAyY0c

COMPANY **STRUCTURE**

FOUNDED: **2020**

COUNTRY: **USA**

OF EMPLOYEES: **2-10**

TOTAL FUNDING: **$ 1,1 M**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- Predictiv has developed a DNA-based Digital Twin technology for predictive medicine. It is a personal genomics solution for whole exome or whole genome sequencing able to identify the genetic predispositions for diseases.
- Predictiv technology exploits AI for sequencing and analysing the whole exome and comparing it with over 20,000 genes and 22,000+ known diseases. Predictiv Digital Twin technology is also able to screen and simulate personalized reactions on 750+ drugs and supplements.
- Predictiv solution is based on a 3 steps process: DNA is collected directly from the patient clipping 5 to 10 fingernails, then DNA is extracted and sequenced using a next generation sequencing technique. Digital Twin is finally created and genetic counselling service is provided to the patient, based on the data generated from the Digital Twin.

Main competitive advantage

Predictiv DNA-based Digital Twin technology is a personal genomics solution able to identify genetic predispositions for diseases and simulate personalized reactions on drugs. Predictiv has developed a simple process accessible by everyone and built around the patient, who can collect DNA samples from home, consult personal Digital Twin on Predictiv interactive platform at any time and share it with other care providers. Through Predictiv platform patients can take preventive actions before symptoms appear.

Value Proposition

- Harnessing AI power, Predictiv aims at achieving the best possible way to simulate, predict and prevent diseases and drug side-effects and promote wellness.
- Through Interactive Platform, Predictiv offers On-demand availability to assist patient and build custom health plans.

Source: Frost & Sullivan, PREDICTIV

UNLEARN.AI

COMPANY **OVERVIEW**

Industry Segment:

Digital twins

Brief Description:

Unlearn.AI has developed TwinRCT solution that creates a prognostic digital twin enabling biopharma partners to carry on successful clinical trials.

Maturity:

Commercialization Currently

Multimedia:

https://www.unlearn.ai/

COMPANY **STRUCTURE**

FOUNDED: **2017**

COUNTRY: **USA**

OF EMPLOYEES: **51-200**

TOTAL FUNDING: **$ 69,9 M**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- Unlearn.AI solution combines AI, Digital Twins, and novel statistical methods to enable smaller and more efficient medical trials. Starting from a specific disease of interest, Unlearn.AI prepares a highly curated dataset of historical trials and registry data, representative of clinical trials in a target indication.
- Once the dataset is prepared, Unlearn.AI solution uses patent pending machine learning methods to train a Digital Twin generator and then evaluate its performance on a test dataset to ensure it is ready to begin generating Digital Twins.
- Unlearn.AI solution creates Digital Twin after patient first visit. TwinRCT incorporate prognostic information from created Digital Twins into randomized controlled trials, so digital twin trajectory is compared with actual patient record at the end of the trial.

Main competitive advantage

Unlearn.AI solution TwinRCT incorporates prognostic information from Digital Twins into randomized controlled trials to enable smaller control groups while maintaining power and generating evidence suitable for supporting regulatory decisions. While a common patient's journey in a clinical trial takes months, TwinRCT generates reliable evidence in a fraction of the time. Exploiting the Digital Twin generator, Unlearn.AI solution uses baseline data to create comprehensive predictions of disease progression for each patient.

Value Proposition

- Unlearn.AI aims to make trials more patient-centric, using smaller control groups and reaching enrolment targets faster. The innovative process will also generate actionable data and insights for regulatory decisions.
- Unlearn.AI works to increase power and confidence, providing reliable evidence suitable for pivotal clinical trials thanks to TwinRCT solution.

Source: Frost & Sullivan, UNLEARN.AI

VIRTONOMY

COMPANY **OVERVIEW**

Industry Segment:

Digital twins

Brief Description:

Virtonomy has created a virtual trial platform that supports the full product life cycle of medical device development utilizing digital twin modelling.

Maturity:

Commercialization Currently

Multimedia:

https://www.youtube.com/watch?v=cvsDtgt5k8E

COMPANY **STRUCTURE**

FOUNDED: **2019**

COUNTRY: **GERMANY**

OF EMPLOYEES: **11-50**

TOTAL FUNDING: **N.A.**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- Virtonomy virtual platform V-Patient supports medical device development using digital twin technology. V-Patient creates virtual patient population based on anatomical variation, demographic diversity and pathological conditions starting from humans and animals' database.
- V-Patient defines inclusion/exclusion criteria, assesses worst-case scenarios to determine the ideal fit of the developing device and how to adjust its design to treat the maximum number of patients. V-Patient also creates average models of certain population groups using Statistical Shape Model -SSM approach.
- V-Patient simulates developing device in the entire virtual target population to investigate how body variations may affect the performance of developing device also identifying the potential for design optimization using parameter analyses.

Main competitive advantage

Virtonomy virtual platform V-Patient supports medical device development and clinical trials with digital twin technology. V-Patient enables to perform development and testing exploiting virtual patients for data-driven clinical trials, thereby accelerating development, reducing risks, expenses, and regulatory burden.

Value Proposition

- Virtonomy aims at shortening time-to-market of medical products by conducting data driven studies on virtual patients: accelerating the time to market while reducing the overall expenses and the medical risks for patients.
- Virtonomy V-Patient contributes to end the use of animals and human testing leveraging virtual patients and allows to close the inequality gap of underrepresented populations.

Source: Frost & Sullivan, VIRTONOMY

PREDISURGE

COMPANY **OVERVIEW**

Industry Segment:

Digital twins

Brief Description:

PrediSurge provides simulation technology to create digital twins of patient anatomies, useful for surgeons to perform automated numerical simulations related to a specific surgery.

Maturity:

Commercialization Currently

Multimedia:

https://www.predisurge.com/wp-content/uploads/2019/03/PS_video_main_header.mp4

COMPANY **STRUCTURE**

FOUNDED: **2017**

COUNTRY: **FRANCE**

OF EMPLOYEES: **11-50**

TOTAL FUNDING: **N.A.**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- PrediSurge has developed a digital twin technology for patient anatomies. The solution makes use of CT-scan medical images to generate 3D modelling of patient-specific anatomy. Users can choose a medical device from a database of digitized models and run an automated numerical simulation of the surgical intervention.
- PrediSurge simulation process is dedicated to designing custom-made stent-grafts that fit the best within patient-specific arteries, in case of aortic aneurysms. PrediSurge 3D modelling technique determines the exact position where fenestrations/branches should be placed on manufactured stent-graft to get right in front of patient collateral arteries when deployed.
- PrediSurge solution provides an online collaborative space where it is possible to share data, exchange between specialists and analyse cases, access simulation results, manage the preoperative process and keep record of all data and inputs.

Main competitive advantage

PrediSurge has developed a digital twin simulation technology that provides non-invasive, fully personalized modeling for lighter and safer procedures. PrediSurge solution is a patient-centric technology for efficient and cost-effective surgery. PrediSurge solution can also be used as end-to-end service to increase industrial value and cut down costs.

Value Proposition

- PrediSurge aims at making patient care more personalized and secured by providing the right data at each procedural stage based on numerical simulation technology.
- Working to develop decision-making tools to better design and implant cardiovascular medical devices, PrediSurge aims to be an active player in the transition from healthcare-driven research to Digital Medicine.

Source: Frost & Sullivan, PREDISURGE

TWIN HEALTH

COMPANY **OVERVIEW**

Industry Segment:

Digital twins

Brief Description:

Twin Health has developed Whole Body Digital Twin, a precision health platform aimed at reversing chronic diseases and improving the human metabolic health.

Maturity:

Commercialization Currently

Multimedia:

https://www.youtube.com/watch?v=z1Rc4r_2PqI

COMPANY **STRUCTURE**

FOUNDED: **2018**

COUNTRY: **USA**

OF EMPLOYEES: **201-500**

TOTAL FUNDING: **$ 198,5M**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- Whole Body Digital Twin is an health platform developed by Twin Health. It provides a dynamic, digital representation of patient metabolism, built from thousands of data points gathered daily from non-invasive wearable sensors and self-reported preferences.
- Whole Body Digital Twin platform delivers precise, personalized guidance about nutrition, sleep, activity, and breathing through an easy-to-use app. It continuously analyses data related to patient health so that healthcare provider and care team can take quick action based on what is good for the patient.
- Whole Body Digital Twin allows to conduct Randomized Controlled Trial - RCT to determine Twin Precision Treatment – TPT technology versus standard care on change in A1C and Type 2 diabetes. Patients had an average HbA1c reduction of 3.1, over 90% achieving type 2 diabetes reversal, and 92% eliminating all diabetes medications, including insulin.

Main competitive advantage

Twin Health developed patent Whole Body Digital Twin health platform that helps to focus on the actions that matter most to reversing chronic metabolic disease. Medical research has shown that each person's metabolism functions differently, which creates significant challenges to healthcare providers' ability to understand and customize treatment for each patient. Whole Body Digital Twin technology delivers guidance precisely tailored to each member's unique metabolism improving health.

Value Proposition

- Twin Health is working for safely reduce or eliminate medications over time, providing patients with a guidance from healthcare providers.
- Whole Body Digital Twin technology gives patients freedom from chronic metabolic disease, helping them reverse and prevent multiple chronic metabolic diseases.

Source: Frost & Sullivan, TWIN HEALTH

EXACTCURE

COMPANY **OVERVIEW**

Industry Segment:

Digital twins

Brief Description:

ExactCure has developed a digital twin platform to simulate efficacy and interactions of medicines on patients, based on their personal characteristics.

Maturity:

Commercialization Currently

Multimedia:

https://www.youtube.com/watch?v=8GBBAH2i1sM

COMPANY **STRUCTURE**

FOUNDED: **2018**

COUNTRY: **FRANCE**

OF EMPLOYEES: **2-10**

TOTAL FUNDING: **€ 1,0M**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- ExactCure digital twin solution simulates the interactions of drugs in the body of patients based on their personal characteristics such as age, gender, kidney status, genotype or any other individual parameter with proven influence on a specific medication.
- Based on population pharmacokinetics and by aggregating scientific literature with meta-analysis techniques, ExactCure solution allows to run powerful simulations and adjust the posology, helping them avoid under-doses, overdoses and drug-drug interactions.
- ExactCure digital twin solution is easily accessible via Web browser and allows to receive filtered alerts from patient's Digital Twin, thus helping professionals to reassure their patients by providing individual real-time monitoring of different parameters such as blood analysis, liver and renal functions, genetic profile.

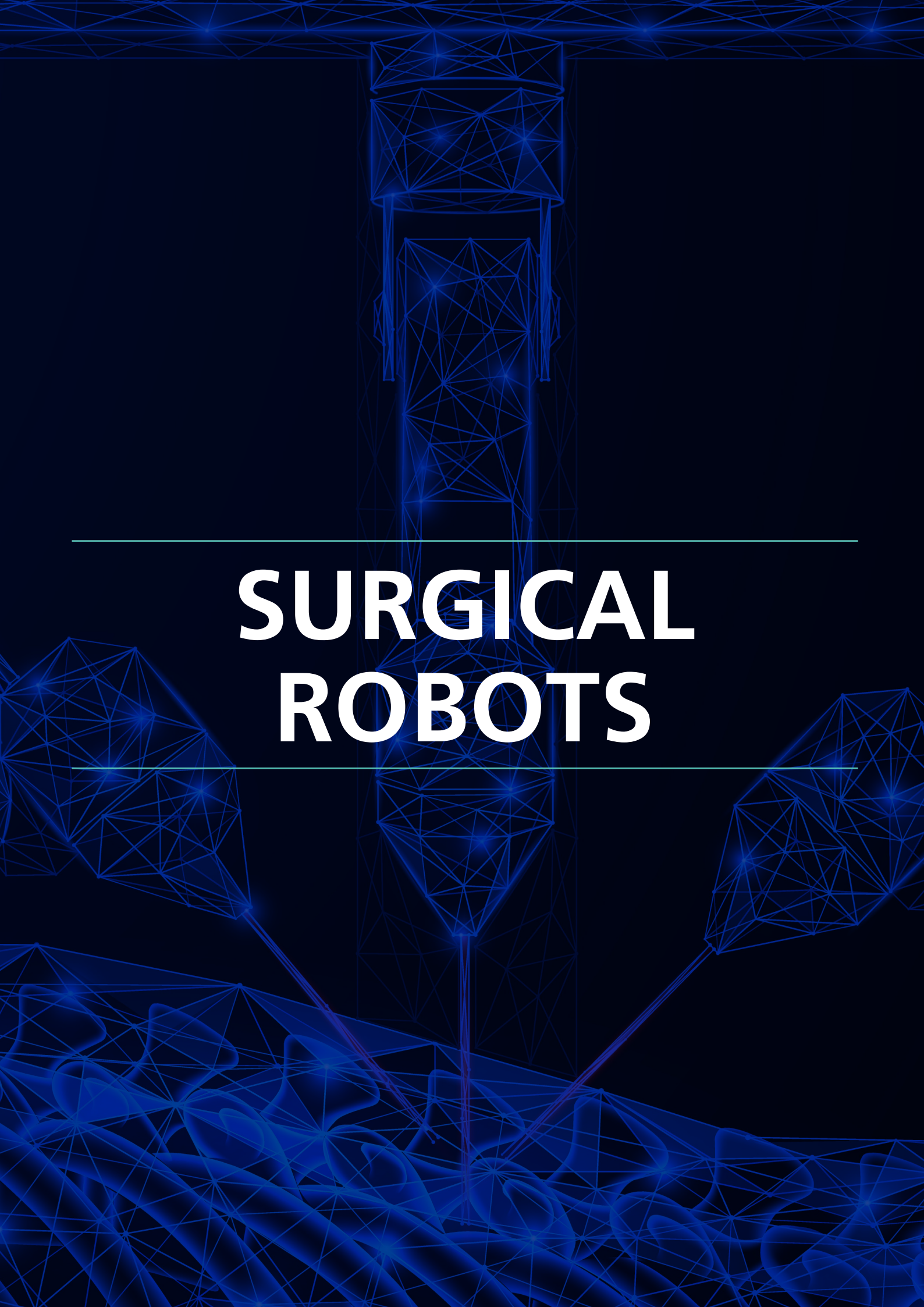
Main competitive advantage

ExactCure developed a digital twin platform able to simulate drug's effectiveness and interaction on patients' bodies. The solution leverages a disruptive software that allows patients predict and visualize the activity of their medication and, at the same time, brings technical innovation personalizing the bio-models of drugs and their effectiveness. ExactCure solution allows a recalibration of the patient's simulations to achieve a unique and relevant parametrization per model.

Value Proposition

- ExactCure aims at becoming the world leader in personalized bio-modelling of medicines starting with personalized bio-models of the effects and interactions of drugs, within the body of each individual.
- ExactCure solutional ping patient to better use drugs, by avoiding under-doses, overdoses and drug-drug interactions.

Source: Frost & Sullivan, EXACTCURE



SURGICAL ROBOTS

The ageing population is causing challenges and creating opportunities not only on the demand side but also in terms of supply with retirements expected to provoke a shortfall of between 55,000 and 150,000 physicians globally by 2030.

Surgical robots are one of several emerging solutions which, in addition to Digital Twins, can help to bridge this gap.

Their promise is being reinforced by continued evolution to support:

- **Novel use-cases**

The latest iteration of robots has multiple articulated arms which enable precise and easy surgeon control from a computer console. Advances in their configuration and connectivity has opened up their application to new types of surgery in which clinicians using remote surgery tools can perform procedures such as implanting a stimulation device into a Parkinson's patient's brain despite them being hospitalized far away.

- **Data-driven decision-making**

Next generation robots are able to integrate thousands of external points of qualitative and quantitative information to make informed decisions and improve processes. Data is vital for predictive analytics to offer the insights that are needed for optimal performance.

- **VR/AR capabilities**

Technologies with applications for various surgical procedures are growing rapidly. VR and AR in particular have the capacity to augment emerging robots and allow them to deliver sophisticated simulations which provide users with immersive and interactive experiences. These benefits are being demonstrated in training across specialties.

Robot-assisted Surgical Devices' (RASD) uptake is being driven by their ability to support with Minimally Invasive Surgeries (MIS)

In addition to leveraging data and VR/AR, RASDs have started to overcome some of the limitations – such as loss of touch and haptic sensations – which are crucial for surgical procedures. In particular, they offer improved dexterity and a solution to physiological tremors that surgeons sometimes experience when using rigid laparoscopic instruments.

RASDs also provide superior bendability and controllability as well as the ability to sense the force applied via shape reconstruction which allows for active payload adjustment.

Technological advances, such as miniature robotic systems to enhance the efficacy of colonoscopic diagnosis and surgery and Minimally Invasive Neurosurgical Intracranial Robots (MINIR) to remove brain tumors more effectively, are further contributing to growth.

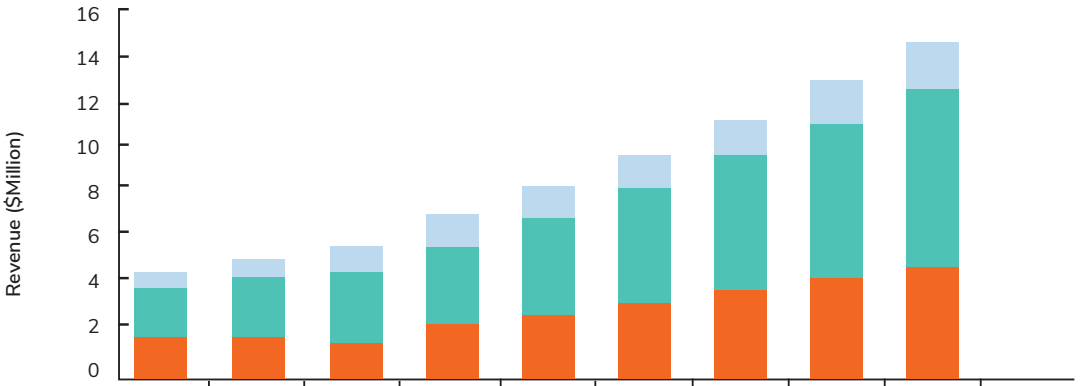
On the demand side, there is increasing adoption of innovative surgical robots (e.g., miniature in-vivo and capsule robots or microbots) that differ from earlier systems. These offer the potential to revolutionize surgery with consistent imaging and telemanipulation capabilities as well as highly miniaturized functionalities.

Finally, favorable reimbursement policies and additional FDA approvals relating to robotic surgical procedures due to their minimal postoperative complications and requirements for relatively short recovery times is inevitably leading to increased patient preference.

Source: Frost & Sullivan

Frost & Sullivan expects the RASD market to be valued at $14.3b globally by 2026

RASD MARKET, REVENUES, GLOBAL, 2018-2026



	2018	2019	2020	2021	2022	2023	2024	2025	2026	CAGR (2021-2026)
RASD Services	0.74	0.79	1.12	1.21	1.31	1.42	1.55	1.69	1.86	9.0%
Instruments and Accessories	2.22	2.55	3.03	3.47	4.08	4.84	5.68	6.57	7.60	17.0%
RASD Systems	1.66	1.83	1.61	2.30	2.79	3.29	3.79	4.29	4.79	15.8%
Total RASD Market	4.62	5.17	5.76	6.99	8.18	9.55	11.02	12.56	14.26	15.3%

YEAR

Growth will stem largely from instruments and accessories to the advantage of dominant leader Intuitive Surgical (US) which boasts an 81% share globally

Intuitive Surgical dominates the global RASD market and generates about $4.5b in systems, instruments and accessories sales. Its da Vinci system accounts for the majority of robotic surgeries globally and is capable of supporting general, prostatectomy, hysterectomy, cardiothoracic and transoral procedures.

Medtronic (US) is also investing heavily in soft tissue robotic systems. The company ranked third in the overall robotics surgery market in 2021 with its recent acquisition of Digital Surgery, which develops digital surgical tools, expected to strengthen its offering. The company's platform approach provides advantages to Medtronic as it can use its product portfolio to provide insights into procedure costs, timing and processes to enhance surgical care. Frost & Sullivan expects its soft tissue *Hugo RAS system* to compete directly with Intuitive Surgical's da Vinci system for market share in thoracic, gynecology, urology, colorectal, bariatric and general robotic-assisted surgical segments.

Zimmer Biomet (US) has a small share in the global robotics-assisted surgery market, well below **Stryker** (US), which is in second place, and Medtronic. Despite having FDA clearance for its ROSA robotic system for spine applications, the company currently concentrates largely on hip and knee applications which represent a much larger market opportunity.

Source: Frost & Sullivan

The rising demand for portability will however broaden the ecosystem and encourage new entrants such as Virtual Incision (US)

Virtual Incision (US) has developed a *Miniaturized In-vivo Robotic Assistant* (MIRA) platform to perform minimally invasive abdominal surgeries such as colon resections.

It promises fewer incisions and less expense whilst, at the same time, eliminating the potential for instrument collisions. In addition, the solution has an auto-track function to guarantee the field of view and allows 360° rotation for multi-quadrant surgery. Virtual Incision's MIRA can be easily moved from room to room and set up can in minutes and has received an FDA Investigational Device Exemption (IDE).

Frost & Sullivan is bullish on the company's outlook as its product addresses the underserved 80% of the overall market which requires smaller and simpler enabling solutions.

Virtual Incision has designed the MIRA platform to increase access to MIS and significantly reduce the time patients have to wait for surgery. By enabling multi-quadrant general surgery and making procedures faster, the platform can increase the surgery volumes that a center can undertake. Its portability should also encourage smaller centers to invest.

Connectivity is also a key requirement to enable telesurgery and is delivered by the likes of Rob Surgical (Spain) via its Bitrack play

Rob Surgical offers the *Bitrack System* for general surgery as well as urology, colon, rectal, gynecology and thoracic procedures.

The solution features multi-quadrant surgical access and operates via a console which offers laparoscope-guided positioning and telemanipulation with a haptic feedback function.

Frost & Sullivan believes the company is well placed as it aims to provide a modular, flexible, and more economical alternative to Intuitive Surgical's da Vinci robot and is working to obtain the CE label so that it can launch in the market.

The Bitrack System's main advantages is its size. With an open console and a single-column design, it occupies less space in an Operating Room (OR) which is often already at a premium. The best approach is to market the product to low-cost care settings. However, more clinical trials are necessary to obtain all FDA approvals.

Source: Frost & Sullivan

The advent of AI is improving performance in the RASD space, notably in the areas of human to robot interaction and system modelling and control

Human to Robot interaction (HRI) needs to focus on ergonomics, comfort, usability, user feedback, and communication. AI in this context can support greater understanding and prediction between the user and the device. Surgeons require regular support to adopt new skills, from remote surgery to interpreting intraoperative haptic feedback via AR.

The key requirements here are cooperative control and touchless manipulation.

Deep reinforcement learning (DRL)-based controllers can help discover exceptions not easily captured in expert systems, support reinforcement learning and enable improved ***system modelling and control*** with respect to surgical robots.

AI-based controllers deployed in this context can evaluate visual information about a piece of equipment's status or quality and take categorical machine alerts and warnings into consideration. They can even use vibration sensor inputs and sound signals to determine process decisions which are similar to the sounds that human operators are subject to. The ability to process visual information, such as the size of a flare, provides differentiation and highlights the DRL-based controllers' real capabilities.

The key requirements here is kinematics and dynamic modelling.

This, combined with the transition from multi-port to single site surgery …

A single-port robotic platform utilizes a surgical arm to place an articulating flexible camera and associated instruments through a single-entry guide. In this configuration, even when occupying a position, the instrument is interchangeable without requiring the intervention of a bedside assistant.

Healthcare professionals believe that reducing the number of incisions to a single access point will reduce complications, trauma, scarring and postoperative pain as well as the need for medication and healing time after surgery. In the post-COVID-19 environment, single-site surgery which combines shorter post-operative recovery times with improved cosmetic outcomes is particularly preferable for both patients and practitioners.

While the initial indication for use of single-port solutions is largely urological and lateral oropharyngectomy procedures, Frost & Sullivan expects the system to receive approval for benign gynecologic surgery. Preclinical evidence indicates that it may also ultimately apply in other subspecialties.

Market participants offering single-port RASD include:

- Titan Medical (US)
- Vicarious Surgical (US)
- Great Belief International Limited (GBIL, China)

Challenges with single-port surgery

The new technology costs more than its laparoscopic predecessors with studies showing that a single-site surgery is $3,000–$6,800 more expensive. The costs may be directly related to the novelty and could decrease over time as more competitors enter the market.

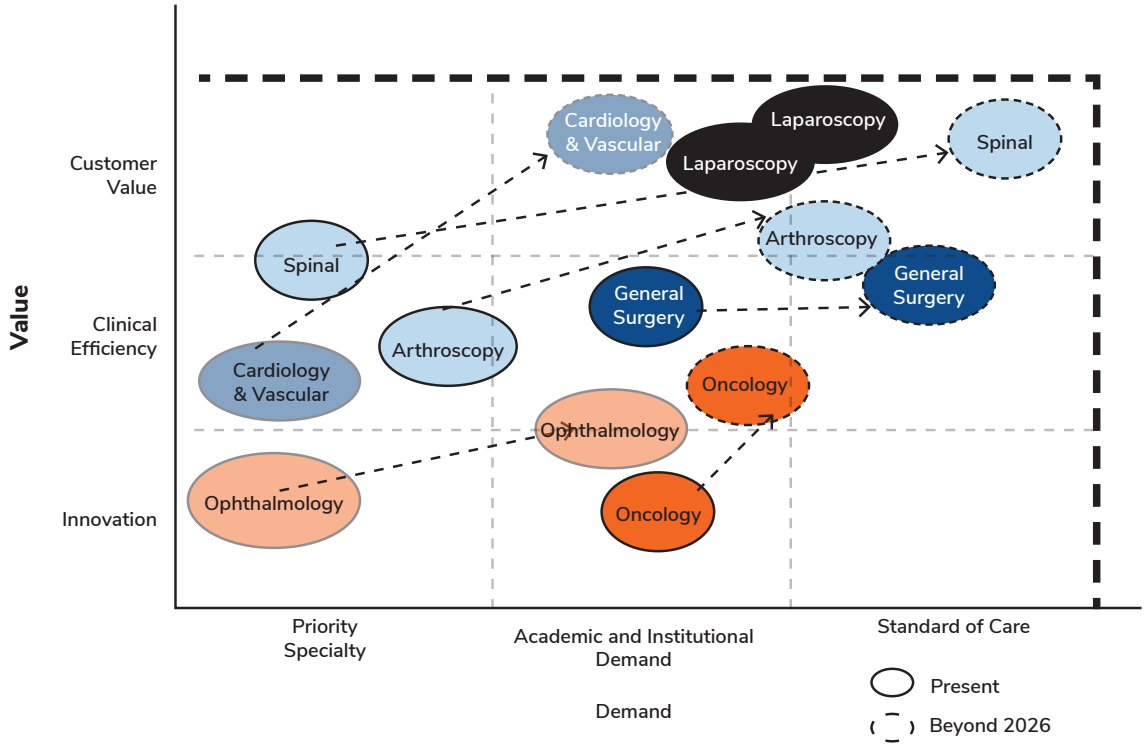
Research also indicates that the time taken to train surgeons in single-port robotics surgery is similar to conventional laparoscopy. Higher adoption rates will only therefore occur when it becomes truly mandatory necessary for residents to possess basic robotics skills.

Source: Frost & Sullivan

… and a shift to address multiple specialties …

As stakeholders respond to evolving patient and customer demands, the RASD market will broaden with the adoption of new business models and a shift to further specialties.

RASD MARKET, CURRENT AND FUTURE ADDRESSABLE SPECIALTIES, GLOBAL, 2021-2026



They bring a range of advantages which differs according to the area of treatment:

Specialty	Advantages
Spinal	• Ease of use, navigation and precision for complex procedures
Cardiovascular and vascular	• Capabilities for large volumes with shorter procedures and fluoroscopic exposure times
General surgery	• Enhanced direct visualization and instrumentation to improves precision
Arthroscopy	• Precision and reduced recalls
Oncology	• Magnified 3D vision with a stable operating field

Source: Frost & Sullivan

… will mean that robotics will gradually become the gold standard of care

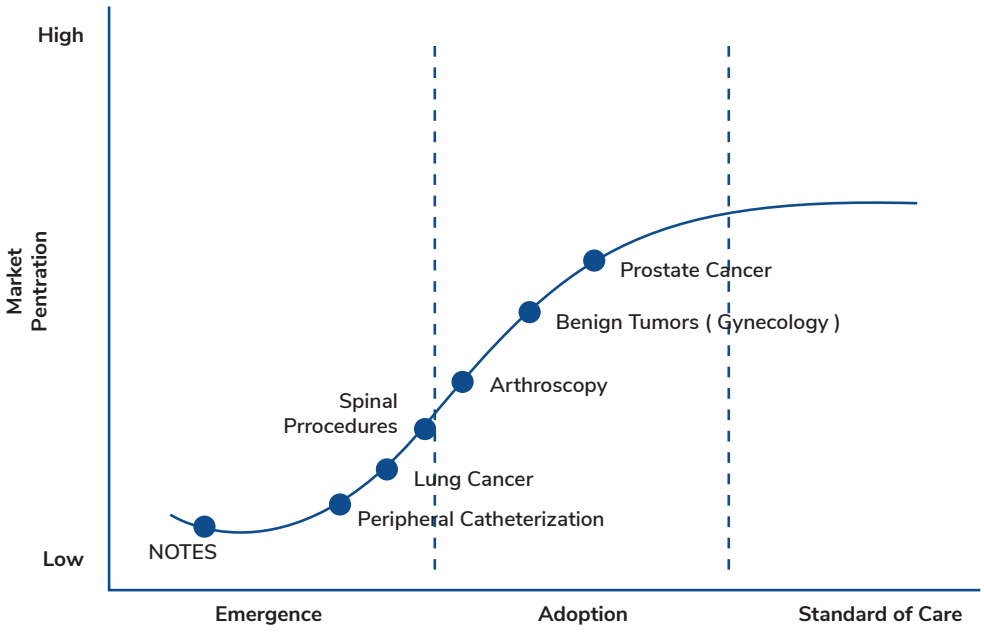
Robotic-assisted surgery serves as an alternative, minimally invasive option for patients with cancer and other conditions. Despite the benefits, clinical research has not yet demonstrated a dramatic difference in outcomes compared with a standard laparoscopic approach.

Precision in performing surgery is the most crucial benefit. However, the effects are less pronounced in diagnosis.

Concerns on costs and the overall benefit of robotic-assisted surgeries remain due to highly variable results, depending on the surgical procedure

It will therefore take time for the treatment of conditions such as prostate cancer with RASD to move from the adoption to the gold standard phase.

RASD MARKET, ADOPTION AND PENETRATION BY CONDITION, GLOBAL, 2021



The FDA is working with collaborators to build the National Evaluation System for Health Technology (NEST) which will collect real-world evidence to evaluate surgical robots amongst other products. The aim of the System is to reduce time and cost to market while increasing the value and use of clinical practice-derived evidence.

In addition to regulation, training is key to further uptake. There is currently no national standard regarding the amount of instruction required but adoption of RASDs is expected to accelerate when their use becomes an integral part of medical school residencies.

Source: Frost & Sullivan

Moving forward, market participants are moving towards a leasing model which offers mutual benefits to "sellers" and "buyers"

Intuitive Surgical has established multiple sales channels to maintain its market dominance. In particular, it has implemented an operating leasing program to lead next stage of its revenue-generating growth strategy.

System leasing approaches can notably facilitate access to emerging markets.

They also provide attractive procurement options to specialty clinics and hospitals by lowering their upfront capital cost. Adopting leasing programs can help surgical robotics manufacturers maintain their revenue generation capabilities and defend their gross margins whilst also facilitating broader market penetration.

The COVID-19 pandemic has added to the healthcare sector's struggle with managing skyrocketing costs and improving services. Robotic surgery-as-a-service approaches are now being evaluated by providers and gaining traction as hospitals look to move capital equipment off their balance sheets and embrace shared-risk models.

They are also sharpening their focus on enabling microsurgery procedures

Most current robotic platforms are not portable and can be difficult for hospitals to accommodate due to their weight and space requirements.

Launching microsurgery solutions therefore offers an opportunity for vendors to address hospitals' challenges in respect of costs, flexibility and accessibility whilst at the same time helping patients by lowering recovery times and minimizes scar tissue.

The rising prevalence of chronic diseases is forecast to cause a surge in demand for microsurgery robots with, in particular, the prevalence of cancer likely to drive their application in oncology treatments.

Microrobots are currently largely used in academic medical centers and community hospitals but are the next generation of low-cost and portable solutions will become easily available for all stakeholders. With significant technological strides in imaging technologies, including AI, and ML, regulatory approvals are also accelerating. Microsure, for example, launched its MUSA robot in 2022 after only receiving the CE mark in 2019.

In the long run, this and other areas will enable vendors to untap the ~90% of the market in volume terms which lies beyond MIS

Minimally Invasive Surgeries comprises 5% to 10% of the surgical procedures market and are currently addressed by heavy and costly equipment which focuses on laparoscopic procedures and oncology. Market participants have largely failed to demonstrate the benefits of robotic surgery over other approaches in other areas and are primarily offering a business model based on recurrent consumables to the Operating Rooms (ORs) of large healthcare systems and providers.

In the future, the focus will switch to the untapped surgery market with vendors pushing portable robots with increased dexterity that can perform microsurgery and esthetic treatment. These robots will offer precision due to control on hand tremors and visual proximity to the patient and are expected to generate higher unit sales due to affordable pricing to the benefit of Ambulatory Surgery Centers (ASCs).

Example of players looking to take advantage of this evolution include Microsure (microsurgery), Robocath (neuro and plastic surgery), Stereotaxis (interventional medicine), Corindus (vascular robotics) and Intravitreal (implants as microrobots).

Source: Frost & Sullivan

MYNUTIA

COMPANY **OVERVIEW**

Industry Segment:

Surgical robots

Brief Description:

Mynutia has developed a surgical robot for eye surgeons aimed at improving the quality of existing therapies and perform technically challenging surgical treatments.

Maturity:

Commercialization Currently

Multimedia:

https://www.youtube.com/watch?v=3vKZ0euTqx0

COMPANY **STRUCTURE**

FOUNDED: **2017**

COUNTRY: **BELGIUM**

OF EMPLOYEES: **2-10**

TOTAL FUNDING: **N.A.**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- Mynutia developed a surgical robot for eye surgery with teleoperated robotic system presenting a unique stabilization system the robot features motion scaling, tremor compensation, and scaled force feedback.
- Mynutia solution's co-manipulated robotic system offers an increased stability and precision, allowing surgeons to maintain a fixed position for prolonged sessions. The device consists of a parallel arm mechanism with a mechanical remote centre of motion and is controlled through a spherical mechanism.
- Mynutia robot has been used on patients with retinal vein occlusion (RVO) for the injection of Ocriplasmin into targeted retinal veins (estimated diameters 100–150µm) with injection durations of up to 10min with successful results.

Main competitive advantage

Mynutia has developed a surgical robot for eye surgery that enabling eye surgeons to operate over 10 times more precisely than is currently possible in clinical practice. The Mynutia surgical robots can improve the quality of existing therapies and perform treatments that were considered technically challenging (or even non-feasible).

Value Proposition

- Mynutia's mission is to leverage the possibilities enabled by its surgical robots to allow surgeons to implement new treatments, increasing the security of the procedures and their rate of success.
- Mynutia wishes to give millions of visually impaired and blind people the chance to regain their sight.

Source: Frost & Sullivan, MYNUTIA

MOON SURGICAL

COMPANY **OVERVIEW**

Industry Segment:

Surgical robots

Brief Description:

Moon Surgical is a medical device company developing a surgical robot for minimally invasive techniques in laparoscopy assistance.

Maturity:

Commercialization Currently

Multimedia:

https://www.youtube.com/watch?v=sWpCpD1zYg8&list=TLGGAWp27D_sTo0wODExMjAyMg&t=86s

COMPANY **STRUCTURE**

FOUNDED: **2019**

COUNTRY: **FRANCE**

OF EMPLOYEES: **11-50**

TOTAL FUNDING: **€ 36,8M**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- Moon Surgical has developed a surgical robot able to bring the surgeon back to the bedside, using a co-manipulation paradigm where system utilizes mechanically transparent haptic interfaces as its primary manipulation tool.
- Moon Surgical robot requires no calibration and no registration. Two mechanically transparent arms expand towards the surgeon offering no resistance when surgeon wants to move the instruments. Once the surgeon stops moving the system remains stable, anchoring the instrument in the needed position.
- Moon Surgical solution allows any instrument to be attached to the system and enhanced in less than a second. The system is engineered with redundant degrees of freedom, intelligent algorithms, and ambient sensors, which all enable adaptability and setup automation.

Main competitive advantage

Moon Surgical has developed a surgical robot for minimally invasive techniques proposing a robotically enabled approach to high-volume surgeons. The developed system intends to be at the bedside with surgeons, augmenting them by giving control over all their instruments and fitting perfectly inside the workflow. The solution is easy to use and brings new adaptability on robotic surgery.

Value Proposition

- Moon Surgical wishes to empower surgeons with complete control, renewed confidence, and technology adaptable to any situation encountered.
- Moon Surgical aims at bringing robotic surgery to high-volume surgeons, adapting robotically assisted surgery to surgeons' regular practice efforts and changing the way in which the surgeon interacts with the system.

Source: Frost & Sullivan, MOON SURGICAL

AIM MEDICAL ROBOTICS

COMPANY **OVERVIEW**

Industry Segment:

Surgical robots

Brief Description:

AiM Medical Robotics is developing MRI robotic system for use in neurosurgical procedures.

Maturity:

Under Development

Multimedia:

https://www.aimmedicalrobotics.com/

COMPANY **STRUCTURE**

FOUNDED: **2018**

COUNTRY: **USA**

OF EMPLOYEES: **2-10**

TOTAL FUNDING: **$ 3,4M**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- AiM Medical Robotics is developing an MRI-compatible advanced robotic system that is precision-focused, portable, and can be used with any diagnostic MRI scanner. AiM solution can be manually transported from an MRI scanner to another and easily repositioned.
- AiM is bringing together best-in-class robotics and deep clinical expertise to develop new robotic motion platform. AiM platform, through sensors, actuators and controllers is built and configured to create and control precise motions within MRI scanner.
- AiM solution has automatic procedural planning process and allows for real time, MRI guided feedback from live imaging, helping physician to live watching instrument and tissues, thus targeting an optimized workflow for a particular application.

Main competitive advantage

AiM Medical Robotics is developing neurosurgical robot-assisted surgery platform for surgeons and patients. With worldwide exclusive license to this technology, AiM's platform is designed to be cost-efficient, streamlined, and differentiated in its ability to help improve outcomes for patient undergoing neurosurgery for functional brain disorders like Parkinson's and epilepsy.

Value Proposition

- AiM Medical Robotics is working to improve outcomes for patients undergoing neurosurgery for functional brain disorders and cancer.
- AiM Medical Robotics aims at reducing procedure times, eliminating error rated and improving patient outcomes.

Source: Frost & Sullivan, AIM MEDICAL ROBOTICS

ACCELUS

COMPANY **OVERVIEW**

Industry Segment:

Surgical robots

Brief Description:

Accelus has developed expandable lumbar fusion systems leveraging proprietary Adaptive Geometry technology to accelerate minimally invasive spine surgery.

Maturity:

Commercialization Currently

Multimedia:

https://www.youtube.com/watch?v=pd2llfwwxtw

COMPANY **STRUCTURE**

FOUNDED: **2021**

COUNTRY: **USA**

OF EMPLOYEES: **51-200**

TOTAL FUNDING: **$ 12M**

REVENUES: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- Accelus has developed FlareHawk, a multidirectional expandable lumbar fusion device, featuring Adaptive Geometry technology. This patented technology delivers multiplanar expansion in height (7 to 12mm), width (7 up to 11mm) and lordosis (0°, 6°).
- Adaptive Geometry Technology, thanks to its open architecture, allows for substantial graft delivery post implantation into and through the implant into the surrounding disc space. Graft volume is only restricted by the volume of disc removed.
- The utilization of Accelus FlareHawk device and Adaptive Geometry technology has interesting results: 97.4% of levels achieved fusion, based on Bridwell - Lenke grading, with 0 reported adverse device related events on 129 patients. 100% of the surgeries were performed utilizing autograft and or allograft.

Main competitive advantage

Accelus developed expandable lumbar fusion system FlareHawk with insertion profile smaller than several other commercially available expandable intrabodies. Its minimal insertion profile and instrumentation is design to respect the patient's anatomy while facilitating the surgeon's preferred technique such as endoscopically assisted TLIF, minimally invasive surgery (MIS) TLIF and Open TLIF. The technology developed enables the company to access previously unserved markets through a pragmatic approach to minimally invasive spine surgery.

Value Proposition

- Accelus aims at accelerating minimally invasive spine surgery through high-performance culture, procedure-enabling technology and broad accessibility.
- Accelus leverages knowledge and technology to solve the clinical challenges of spine surgery through innovation, allowing surgeons to address complex pathology and developing new products.

Source: Frost & Sullivan, ACCELUS

PRINCIPAL ABBREVIATIONS

AI	*Artificial Intelligence*
APLIS	*Anatomical Pathology Lab Information Management System*
AR	*Augmented Reality*
ASC	*Ambulatory Surgery Center*
B	*Billion*
B2B	*Business-to-Business*
CAGR	*Compound Annual Growth Rate*
CDx	*Companion Diagnostic*
CTC	*Circulating Tumor Cell*
ctDNA	*Circulating Tumor DNA*
DL	*Deep Learning*
DNA	*Deoxyribonucleic Acid*
DRL	*Deep Reinforcement Learning*
DT	*Digital Twin*
ELISA	*Enzyme-linked Immunosorbent Assay*
EMR	*Electronic Medical Record*
H&E	*Hematoxylin and Eosin*
HRI	*Human to Robot Interaction*
ICU	*Intensive Care Unit*
IDE	*Investigational Device Exemption*
IHC	*Immunohistochemistry*
IoT	*Internet of Things*
ISH	*In Situ Hybridization*
IVD	*In Vitro Diagnostics*
KPI	*Key Performance Indicator*
LDT	*Lab-developed Test*
LIS	*Laboratory Information System*
M	*Million*
M&A	*Mergers & Acquisitions*
MDx	*Molecular Diagnostics*
MINIR	*Minimally Invasive Neurosurgical Intracranial Robots*
MIS	*Minimally Invasive Surgeries*
ML	*Machine Learning*
MRD	*Molecular Residual Disease*
OEM	*Original Equipment Manufacturer*
OR	*Operating Room*
PCR	*Polymerase Chain Reaction*
POC	*Point-of-Care*
POCT	*Point-of-Care Testing*
R&D	*Research & Development*
RASD	*Robot-assisted Surgical Device*
RNA	*Ribonucleic Acid*
TDx	*Tissue Diagnostics*
UK	*United Kingdom*
US	*United States*
VC	*Venture Capital*
VR	*Virtual Reality*
WSI	*Whole Slide Imaging*

Source: Frost & Sullivan

ABOUT INTESA SANPAOLO INNOVATION CENTER:

Intesa Sanpaolo Innovation Center is the company of Intesa Sanpaolo Group dedicated to innovation: it explores and learns new business and research models and acts as a stimulus and engine for the new economy in Italy. The company invests in applied research projects and high potential start-ups, to foster the competitiveness of the Group and its customers and accelerate the development of the circular economy in Italy.

Based in the Turin skyscraper designed by Renzo Piano, with its national and international network of hubs and laboratories, the Innovation Center is an enabler of relations with other stakeholders of the innovation ecosystem - such as tech companies, start-ups, incubators, research centres and universities - and a promoter of new forms of entrepreneurship in accessing venture capital. Intesa Sanpaolo Innovation Center focuses mainly on circular economy, development of the most promising start-ups, venture capital investments of the management company Neva SGR and applied research

For further detail on Intesa Sanpaolo Innovation Center products and services, please contact

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ABOUT FROST & SULLIVAN:

For over five decades, Frost & Sullivan has become world-renowned for its role in helping investors, corporate leaders and governments navigate economic changes and identify disruptive technologies, Mega Trends, new business models and companies to action, resulting in a continuous flow of growth opportunities to drive future success.

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